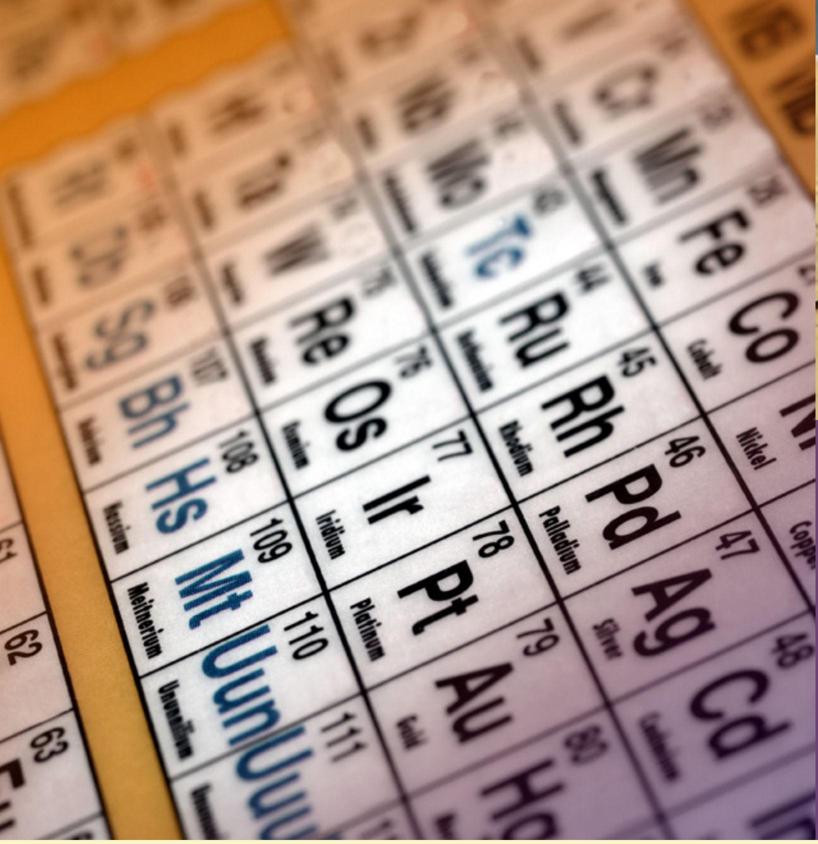


The Lean and Chemicals Toolkit


www.epa.gov/lean

How to Use This Toolkit

This toolkit uses icons in the page margins to help you find and follow important information.

Key Point

Key Point identifies an **important point** to remember

Key Term

Key Term defines an **important term** or concept

New Tool

New Tool presents a **technique or resource** that helps capture, communicate, or apply new knowledge

Caution

Caution highlights a **potential problem** that could arise without close attention

Chapters also include one or more "**To Consider**" text boxes that contain questions to help you explore how the information relates to your organization.

This is one of a series of Lean and Environment publications from the U.S. Environmental Protection Agency. For more information, visit the EPA Lean and Environment website at www.epa.gov/lean.

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Disclaimer about Waste Definitions

Environmental Waste

This document describes techniques that can generally reduce regulatory compliance burdens by removing or minimizing regulated materials, wastes, and releases from facilities. However, this document is not intended to provide specific information or advice about a facility's compliance with any regulations or laws. This document also recommends involving staff with environmental health and safety (EHS) expertise in operational changes at facilities to maximize chemical waste reductions and to assist with compliance with environmental, health, and safety regulations. EHS staff should contact the appropriate regulatory authorities for more information about compliance requirements.

Hazardous Waste

This document uses the term "hazardous waste" to refer to any compound containing chemicals that require safe disposal. This term is used to define a broad range of waste streams; these "wastes" are not necessarily the same as those classified under the Resource Conservation and Recovery Act (RCRA), the law and regulations that govern the management and disposal of wastes. The law and regulations include a specific definition of the term "hazardous waste" and that definition should not be confused with the general terminology used in this document. In addition, this document does not provide information or advice about identifying regulatory hazardous wastes or complying with the hazardous waste regulations. You should contact the appropriate regulatory agencies for information about the hazardous waste regulations applicable to your organization or facility. (For more information about wastes, see www.epa.gov/epawaste).

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Executive Summary

This *Lean and Chemicals Toolkit* describes practical strategies for using Lean manufacturing—the production system developed by Toyota—to reduce chemical wastes while improving the operational and environmental performance of manufacturing and industrial businesses. As used in this toolkit, "chemical waste" refers to any aspect of chemical use and management that does not add value from a customer's perspective, including:[1]

- Excess or unnecessary use of chemicals
- Use of hazardous chemicals that could harm human health, worker safety, and/or the environment
- Hazardous wastes generated from production and the disposal of products

This toolkit is a supplement to EPA's *Lean and Environment Toolkit* (www.epa.gov/lean/toolkit), which addresses all types of environmental wastes.

Why Address Chemical Wastes with Lean

Benefits from addressing chemical wastes through Lean implementation:

- **Learn to see the hidden costs of chemical wastes**. Although often buried in overhead costs, chemical wastes can have major costs for businesses. Effective Lean and chemical management strategies can drastically reduce costs, risks, and safety hazards.
- **Enhance the effectiveness of Lean techniques**. Effectively applying Lean techniques to environmentally sensitive "monument" processes can have big pay offs for environmental performance and bottom-line results.
- **Deliver what customers and employees want**. Organizations that develop products with fewer hazardous chemicals and operate hazard-free production processes have the potential to gain competitive advantage.

This toolkit describes how to identify and reduce chemical wastes alongside the range of other wastes targeted by Lean, thereby achieving better results without distracting Lean from its focus on waste elimination and continual improvement.

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[1] See the disclaimer on page ii regarding the definitions of wastes used in this toolkit.

Driving Out Chemical Wastes with Lean Events

Value stream mapping events and kaizen rapid process improvement events are very effective ways to identify and eliminate chemical wastes. Strategies include:

- **Value Stream Mapping Events**: Add chemical metrics or show environmental inputs and outputs on the process boxes on value stream maps, as a way to discover new process-improvement opportunities.

- **Kaizen Events**: Involve environmental health and safety (EHS) personnel strategically in kaizen events, ask questions to identify the root causes of chemical wastes, and target certain kaizen events on chemical wastes.

Lean Chemical Management

Many Lean manufacturing strategies—including right-sized equipment and containers, just-in-time (JIT) delivery, point-of-use storage, 6S (5S + Safety), kitting, and visual controls—can dramatically reduce chemical use, waste, and risk. Example chemical management strategies that support Lean goals include:

- **JIT and Chemical Management Services**: Having chemicals delivered when you need them in the amounts that you need supports Lean goals while also reducing risks and wastes. Contracting with companies that provide chemical management services can remove even more waste.

- **Right-Sizing**: Limit unnecessary use of chemicals and increase process efficiency by making equipment and containers the right size for the task.

- **Applying Lean to Hazardous Waste Management**: Use Lean to improve chemical and waste management "support" processes, such as waste-collection processes and compliance-reporting activities.

- **Point-of-Use Storage**: Adopt proper maintenance and control procedures to prevent regulatory compliance and worker health and safety issues associated with point-of-use storage of chemicals.

- **Visual Management**: Reinforce best practices for using and disposing of chemicals and hazardous wastes with visual controls, standard work, 6S (5S + Safety), and Total Productive Maintenance.

Designing Products and Processes that Use Less Hazardous Chemicals

Lean product and process design methods—such as 3P, Design for Manufacturing and Assembly, and Quality Function Deployment—are powerful tools for eliminating harmful uses of chemicals in products and processes. Strategies for incorporating chemical considerations into Lean design include:

- Incorporate environmental design criteria and "green chemistry" principles into Lean design methods.
- Draw on Design for Environment resources such as clean technology assessments and sector-based best practices to identify safer alternatives.
- Look for opportunities to meet customer needs with products and services that eliminate or use minimal amounts of hazardous chemicals.

A Vision for Lean and Chemicals

As organizations evolve their operations using Lean, it can be useful to think about better ways to make and deliver high quality products and services that customers want, when they want them, and without things that do not add value. A guiding vision for Lean and chemicals efforts could include two parts:

- Produce high-quality products and services that do not contain hazardous chemicals that customers did not request.
- Develop products that can decompose naturally at the end of their use or become high-quality raw materials for new products.

Getting Started with Lean and Chemicals

There are many ways to get started with reducing chemical wastes and improving business results using Lean. An important initial step is for Lean champions or operations managers to connect with EHS personnel to discuss opportunities to reduce chemical wastes with Lean. Consider trying out some of the strategies and tools in this toolkit, start measuring chemical use and hazardous waste generation along with Lean metrics, and discover the benefits of improved Lean and chemicals management for your organization.

Preface

Purpose of This Toolkit

Key Point

*This **Lean and Chemicals Toolkit** offers Lean implementers practical strategies and techniques for improving common Lean results related to time, cost, and quality while also reducing risk and enhancing environmental performance related to all aspects of chemical manufacturing, management and use*. This toolkit is intended to introduce Lean practitioners from chemical manufacturing companies, companies that use chemicals in their products and/or production processes, and small businesses that use chemicals on an incidental basis to strategies for identifying and eliminating chemical "waste" and risk as part of Lean. Environmental Health and Safety (EHS) professionals at these companies will also find useful information in this toolkit. Finally, the toolkit introduces Lean practitioners to the wide array of chemical waste management information and resources available from EPA and other organizations.

Key Term

The "Lean" methods discussed in this toolkit are organizational improvement methods pioneered in the Toyota Production System. *Lean production* and *Lean manufacturing* refer to a customer-focused business model and collection of methods that focus on the elimination of waste (non-value added activity) while delivering quality products on time and at a low cost. The toolkit assumes that you are familiar with Lean methods. For those who want to learn more about Lean, see EPA's Lean and Environment website (www.epa.gov/lean).

Key Questions Addressed by the Toolkit

Lean works well when it focuses on identifying and eliminating waste. Environmental improvement and chemical reduction efforts that could distract Lean efforts from this prime focus may not get much traction. By contrast, this toolkit contains strategies and techniques that can enable Lean practitioners to easily identify chemical wastes and improvement opportunities alongside the myriad other wastes and improvement opportunities uncovered by Lean. To accomplish these objectives, the toolkit aims to answer the following questions:

What is the relationship between Lean and chemicals?

By eliminating manufacturing wastes, such as unnecessary chemical use, and improving management of chemicals, businesses can reduce costs and risk, while better meeting customer needs. In addition, companies that eliminate harmful chemicals from their products can gain potential market advantage from eco-labeling and certification programs. Chapter 1 describes the benefits of learning to see chemical wastes as part of Lean implementation and combining Lean and chemical use reduction efforts. Chapter 2 provides background information on chemical manufacturing, management, and use.

How can one reduce chemical wastes using Lean events?

A key step in effective Lean and chemical efforts is learning to see chemical wastes in the context of Lean methods and identifying where to target chemical reduction activities. Chapter 3 examines specific techniques for using Lean methods to identify and eliminate chemical wastes. Methods examined in this chapter include value stream mapping and kaizen events.

How can one improve chemical management in Lean workspaces?

Lean implementation can bring significant changes to how work is configured in the workplace and, as a result, to how chemicals are managed. Chapter 4 describes how Lean strategies such as cellular manufacturing, just-in-time delivery, and "right-sizing" affect chemical management, and presents Lean approaches to chemical and hazardous waste management. Chapter 5 examines workspace-level opportunities to eliminate chemical wastes, focusing on Lean methods such as point-of-use storage, 6S (5S + Safety), visual controls, and Total Productive Maintenance (TPM).

How can Lean design tools be used to reduce chemical costs and risks?

Lean design methods offer a powerful way to reduce chemical use and risk in products and processes. By asking the right questions related to chemicals during Lean design efforts, organizations can better design products and processes that reduce costs and risk while also meeting customer needs. Chapter 6 provides an overview of Lean design tools—such as 3P, Quality Function Deployment, and Design for Manufacturing and Assembly—and describes opportunities for integrating chemical considerations and environmental design principles.

A Vision for Lean and Chemicals Efforts

Lean is all about meeting customers' needs. In that sense, eliminating chemical wastes is a natural fit with Lean principles. As organizations evolve their operations using Lean, it can be useful to articulate a guiding vision for how chemicals fit into the following equation: *make and deliver high-quality products and services that customers want, when they want them*.

In their well-regarded book on industrial design, titled *Cradle to Cradle: Remaking the Way We Make Things*, William McDonough and Michael Braungart present a compelling vision that is highly relevant to Lean and chemicals initiatives. Two key components of this vision include: [2]

- Produce products and services that do not consume (during production or use) or contain toxic or hazardous chemicals that customers did not ask for and did not know were included.

[2] William McDonough and Michael Braungart, *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, 2002.

- Produce products that, when their useful life is over, do not become useless waste but can be composted to become food for plants and animals and nutrients for soil; or alternatively, that can return to industrial cycles to supply high-quality raw materials for new products.

This toolkit can be a springboard for working towards this vision. It describes strategies and tools for reducing the risks, costs, and time associated with using chemicals and managing hazardous wastes, while also supporting Lean's overall goals of continual improvement and waste elimination.

Given recent regulatory, product labeling, and consumer preference trends, it is likely that pressures to identify and eliminate harmful aspects of chemical use will increase in the future. Companies that can leverage their Lean initiatives to identify and eliminate chemical waste can enjoy significant competitive advantages as they seek to win and retain customers.

To Consider

As you read this toolkit, consider these questions:

- Would you like to reduce chemical risks to employees?
- Would you like to eliminate hidden costs from chemical wastes?
- Would you like to reduce or eliminate the regulatory burden associated with chemicals and hazardous wastes?
- Would you like to enhance the effectiveness of Lean techniques?

This toolkit offers a range of ideas for achieving these goals. Continue reading to learn more about chemicals and discover practical strategies and tools for reducing chemical wastes through Lean implementation.

CHAPTER 1

Introduction

This chapter includes the following sections:

- Learning to See Chemical Wastes
- Benefits of Addressing Chemicals with Lean

Learning to See Chemical Wastes

Chemicals play an important role in manufacturing and service products and processes across diverse sectors of the U.S. and world economy. Chemicals can also be a major source of environmental waste, risk, and impacts. Many chemicals have properties that can significantly affect human health, safety, and the environment. Chemicals can affect worker health through exposure in the workplace or customer health through exposure during product handling or use. Chemicals can also affect human health and ecosystem health through releases to air, water, or land during production activities or after products are discarded.

Key Term

What is chemical waste?[3] As considered in this toolkit, *chemical waste* is any unnecessary or excess use of a chemical substance that could harm human health or the environment when released to the air, water, or land. When thought about in a Lean context, chemical wastes include any aspects of chemical management and use that do not add value to meet customer needs. Chemical waste is a subset of "environmental waste" described in EPA's *Lean and Environment Toolkit* (www.epa.gov/lean/toolkit) as an unnecessary or excess use of resources or a substance released to the air, water, or land that could harm human health or the environment. Specific types of chemical waste can include:

- Use of more chemicals than necessary to add value
- Use of chemicals with attributes that can harm human or ecosystem health or create safety risks
- Chemicals that are purchased but never used and must be discarded
- Chemical by-products and waste streams

[3] See the disclaimer on page ii regarding the definitions of wastes used in this toolkit.

While there may be some chemical waste savings on the coattails of more traditionally targeted wastes in Lean events, other types may go unnoticed. This toolkit examines key tools for helping organizations to see—and eliminate—chemical wastes.

Benefits of Addressing Chemicals with Lean

Key Point

Lean provides powerful tools for delivering value to customers in a manner that minimizes waste, risk and adverse impacts from chemical wastes. *Explicit consideration of chemical waste and risks during Lean implementation can create significant value for an organization helping to deliver quality products and services that customers want, when they want them*. Research sponsored by EPA and others shows that some chemical use and waste reduction benefits typically ride the coattails of Lean efforts, yet other opportunities to reduce wastes, risks, and non-value added activity associated with chemicals may be overlooked. There are three key benefits of addressing chemicals with Lean, as listed in Box 1 and further described below.

Key Benefits of Addressing Chemicals with Lean (Box 1)

1. Learn to see the hidden costs of chemical wastes and hazards.
2. Enhance the effectiveness of Lean techniques.
3. Deliver what customers and employees want.

Considering chemical wastes, risks and impacts during Lean efforts can increase value, accelerate Lean implementation, decrease material costs, and reduce liability and the risk of compliance violations. Box 2 illustrates the types of compelling results that can be achieved when chemical wastes and risk are considered during Lean implementation.

Example Results From Lean and Chemical Waste Reduction Efforts (Box 2)

- ✓ The **Lockheed Martin** Manassas, Virginia plant applied Lean techniques to chemical and waste management activities resulting in the reduction of chemical storage space from 64,000 square feet to 1,200 square feet.
- ✓ **Robins U.S. Air Force Base** in Georgia applied Lean activities to its flight line, resulting in the reduction of hazardous chemical use and hazardous wastes generated by 20 percent.
- ✓ **Boeing's** Everett, Washington plant used Lean to reduce the amount of chemicals on the shop floor by 23 percent.

1. Learn to See Hidden Chemical Wastes and Hazards

Key Point

Learning to see and eliminate waste is a cornerstone of Lean initiatives. *Chemical wastes are often a sign of inefficient production, and they frequently indicate opportunities for saving costs and time*. Lean's focus on eliminating non-value added activity is excellent at driving down the volume of chemical use and wastes, producing important competitiveness and environmental benefits. However, some aspects of chemical wastes—including health, safety and environmental risks posed by toxic chemicals—often go unaddressed (or under addressed) by Lean initiatives.

When grouped together, wastes associated with chemicals can result in huge costs to business. These costs include raw material and disposal costs, as well as costs for compliance management activities and pollution control processes and equipment. Learning to see environmental wastes during Lean efforts can open significant business improvement opportunities, further strengthen Lean results, and improve environmental performance.

Key Point

Companies have found that as much as 40 percent of their chemical supplies were going unused and directly becoming hazardous waste as they expired on the shelf or became obsolete.[4] Furthermore, Lean tools such as 6S (5S + Safety), standard work, and visual controls can be used to ensure that chemicals and hazardous wastes are handled and disposed of properly.[5] Using Lean principles to improve chemical and hazardous waste management processes can have big pay-offs for environmental performance and bottom-line results.

Several types of chemical waste costs are often hidden from view and buried in overhead or support cost centers. These "hidden" costs include:

- **Regulatory Compliance Requirements:** Chemical use can require significant regulatory compliance, permitting, and reporting activity, depending on the amount and types of chemicals used. Chemical use and wastes can trigger diverse reporting requirements, such as those under the Emergency Planning and Community Right to Know Act (EPCRA) and Toxics Release Inventory (TRI). Chemical use can also drive the need to prepare Risk Management Plans under the Clean Air Act and Storm Water Pollution Prevention Plans under the Clean Water Act. Regulatory permitting, compliance and reporting activities can have direct costs related to fees, fines, consultants, and compliance management tools, as well as significant staff labor costs.

- **Costly Pollution Control Equipment:** Chemical use can require costly hazardous waste management and pollution control equipment and processes. For example, the need for wastewater treatment facilities and air pollution control devices may be driven by a

[4] U.S. EPA, "Lean Manufacturing and the Environment: Lean Manufacturing and the Environment: Research on Advanced Manufacturing Systems and the Environment and Recommendations for Leveraging Better Environmental Performance," October 2003, www.epa.gov/lean/leanreport.pdf, p. 25.

[5] See the disclaimer on page ii regarding the definitions of wastes used in this toolkit.

business' use of a small number of chemicals. Also, personal protective equipment may be required for workers; this can be costly and, in some cases, can hinder worker productivity.

- **Raw Material and Disposal Costs:** Raw material and disposal costs associated with chemical use can be substantial. While direct use of chemicals in a process may be visible, potential future costs such as disposal of hazardous wastes, expired chemicals or off-specification chemicals in inventory may not be readily visible during a Lean event. Also, not readily visible, is the money saved by not having to purchase the quantity of materials.

Chemical substitution, process changes, and other strategies can reduce the need for such non-value added activities. For these reasons, learning to see and eliminate chemical wastes can greatly improve the time, quality, and cost results of Lean initiatives.

2. Enhance the Effectiveness of Lean Techniques

Explicit coordination of Lean and chemical waste reduction initiatives can lead to compelling organizational and environmental improvement results. For example, shifts to just-in-time production and "right-sized" chemical procurement can eliminate many of the spill prevention and regulatory compliance burdens of storing large amounts of chemicals on-site. Lean thinking can also be applied to various environmental processes, such as chemical and waste management.

Benefits of Coordinating Lean and Chemical Management Activities (Box 3)

- ✓ Reduce chemical input and waste disposal costs
- ✓ Improve process flow and reduce lead times
- ✓ Reduce chemical use or releases below regulatory thresholds
- ✓ Lower regulatory non-compliance risk
- ✓ Meet customer expectations
- ✓ Improve environmental quality
- ✓ Reduce the likelihood of spills and safety accidents
- ✓ Improve employee health and job satisfaction
- ✓ Improve relationships with facility neighbors

Key Point

Proactive Lean and environment coordination can also anticipate and ease environmental constraints to leaning "monument" processes, thereby enabling large performance gains. Monuments are production processes or process steps that are difficult to "Lean." Monuments often involve large equipment that can have environmental permitting, or regulatory constraints. These constraints are typically driven by the chemicals used in these processes—and can make these monuments difficult or costly to move. Monuments can complicate Lean efforts and significantly hinder performance improvement. Typical monuments include painting, parts cleaning, and metal finishing processes.

Shifting to smaller equipment that can be incorporated into manufacturing cells better supports Lean principles such as one-piece flow. This transformation, however, typically requires careful coordination to ensure that regulatory compliance, safety protection, and pollution control requirements driven by chemicals are anticipated and addressed. EHS personnel can help to identify environmentally friendly alternatives, and ensure that process changes can be made as quickly as possible.

3. Deliver What Customers and Employees Want

Most customers do not want to buy products that contain toxic chemicals. Public pressure to reduce the presence of toxic substances in products is increasing, enhanced by news reports of hazardous substances in products ranging from toys to toothpaste. Regulatory pressures in some U.S. States, and from the RoHS and REACH directives in the European Union, are increasing the scrutiny of industrial chemical use (see Box 4). At the same time, eco-labeling and certification programs provide incentives to reduce the use of toxic chemicals.

Key Point

Companies that can deliver products and services with fewer chemicals have the potential to capture significant competitive advantage, provided that there are not significant sacrifices in time, quality, or cost. In many markets, products that are made with non-hazardous and non-toxic chemicals can attract new customers.

Key Point

Explicit consideration of chemical waste in Lean initiatives can also improve the work environment for employees and address neighbors' concerns. Eliminating or reducing chemicals in the workplace can reduce worker exposure to toxic substances, decrease noxious odors and irritants that can affect productivity and job satisfaction, and create a cleaner and safer workplace. Efforts to reduce toxic chemicals in the workplace can pay big dividends with regard to employee morale and productivity, while fostering good relationships with facility neighbors.

The European Union's RoHS and REACH Directives Are Influencing Businesses' Use of Chemicals (Box 4)

Restriction of Hazardous Substances Directive (RoHS)

This European Union directive, which took effect in 2006, restricts the use of the following six hazardous materials in the manufacture of various types of electronic and electrical equipment.

- Lead
- Mercury
- Cadmium
- Hexavalent chromium
- Polybrominated biphenyls
- Polybrominated diphenyl ether

Registration, Evaluation and Authorization of Chemicals (REACH)

This European Community regulation, effective as of June 2007, requires all manufacturers and importers of chemicals to identify and manage risks linked to the products they manufacture and market. Enterprises that manufacture or import more than one ton of a chemical substance per year are required to register it in a central database. An estimated 30,000 substances will be registered. The REACH regulation gives greater responsibility to industry to manage the risks from chemicals and to provide safety information on the substances.

Getting Started with Lean and Chemicals

There are many ways for an organization to get started with reducing chemical wastes to improve the health of employees, consumers, and the environment. Implementing Lean can also improve business results. While the possibilities can be overwhelming, the important thing is to get started, even if the effort is small. Here are some ideas for beginning a Lean and chemicals effort at your company.

1. Begin the Conversation

As a first step, Lean champions or operations managers should connect with facility EHS personnel to discuss opportunities to reduce chemical wastes with Lean. Even brief conversations can enable EHS personnel to bring valuable information and expertise to the table during Lean events, helping Lean teams to see chemical waste that may be hidden in overhead and facilities accounts.

EHS managers can quickly identify process areas and steps that have the greatest impact on chemical use, risk, and waste. By cross-walking this information with Lean event schedules, managers can prioritize opportunities for involving EHS personnel in value stream mapping and kaizen events.

2. Make Chemicals and their Costs Visible

Consider trying out some of the strategies and tools in this toolkit to make chemical waste more visible during Lean events. Start measuring chemical use and hazardous waste generation along with Lean metrics. Calculate the costs associated with chemical procurement, chemical handling and management, pollution control equipment, and compliance and reporting activities from using chemicals, and map these costs to specific value streams, product lines, or processes. The data does not need to be precise to be useful. Even order of magnitude estimates can help pinpoint areas to look for chemical waste during Lean initiatives.

3. Piggyback on Lean Visual Management Efforts

Look for opportunities to incorporate chemical management and waste reduction opportunities into Lean visual management efforts. Here are a few quick hints:

- Identify places where proper chemical handling, management, and disposal practices can be incorporated into Lean standard work procedures. Too often, environmental management procedures are separate from standard work procedures and are not readily available where the work is done.
- Use clear, easy-to-understand floor markings and placards to identify chemical point-of-use storage stations and containers for collecting hazardous and non-hazardous wastes. Make it easy for shop floor workers to know what they need to do.
- Add items to 6S (5S + Safety) workspace audit checklists to make sure that workers routinely check to ensure that chemicals are properly labeled, stored, used, and disposed.

While these represent a few simple steps to get started with Lean and chemical waste-reduction efforts at your organization, there are multiple ways to be successful. The next chapter provides background information about chemicals, while Chapters 3–6 of this toolkit outline opportunities to reduce chemical wastes using Lean principles and methods. Feel free to choose which of these strategies and tools to start with depending on what is best for your organization.

To Consider

- Are chemicals responsible for major costs, wastes, or risk in your organization? If you don't know, how would you find out?
- How has Lean affected your organization's use of chemicals?
- How could your company benefit from efforts to reduce chemical use or wastes using Lean? (Think about time and cost savings, reduced risks and liabilities, added value to customers, etc.)
- What ideas do you have for reducing chemical wastes using Lean methods?

CHAPTER 2

Chemicals Overview

Understanding chemicals is an important step when undertaking methods to reduce chemical use and waste. This chapter contains the following sections:

- Definition of Chemical Waste
- Understanding the Dangers of Chemicals
- Examples of Hazardous Chemicals
- How to Learn More about Chemicals
- The Chemical Lifecycle

Definition of Chemical Waste

Key Term

As discussed in Chapter 1, *chemical waste* is any unnecessary or excess use of a chemical, or a chemical substance that could harm human health or the environment when released to the air, water, or land. Chemical waste is a subset of "environmental waste" described in EPA's *Lean and Environment Toolkit*.

Many chemical wastes can be classified as hazardous waste. Hazardous wastes are the types of waste that can cause the most damage to human health and the environment.[6] Hazardous wastes can be liquids, solids, gases, or sludge. They can be discarded commercial products, such as cleaning fluids or pesticides, or the by-products of manufacturing processes.

Box 5 lists examples of chemical wastes. While containers used to store hazardous waste have easy-to-spot indicators of chemical waste, other sources may be more difficult to identify, including chemical waste that may be hidden in established processes. Other chemical wastes include excess mixed or unmixed chemicals and materials contaminated with chemicals.

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[6] See the disclaimer on page ii regarding the definitions of wastes used in this toolkit.

Example of Chemical Wastes (Box 5)

- ✓ Chemicals that can no longer be used for their intended use (e.g. aged or surplus inventory)
- ✓ Mislabeled or unlabeled chemicals
- ✓ Abandoned chemicals
- ✓ Material in deteriorating or damaged containers
- ✓ Residuals in chemical containers
- ✓ Diluted solutions containing hazardous chemicals
- ✓ Used photographic fixer and developer
- ✓ Debris contaminated with a hazardous material (rags, paper towels, lab diapers, gloves, etc.)

Understanding the Dangers of Chemicals

Many types of chemicals are hazardous. For safety and security it is important to be able to recognize any dangers involved in storing and using certain chemicals. It is also important to know about chemical characteristics when disposing of chemicals to ensure that those wastes are disposed of properly. Hazardous chemical warning signs exist to warn people of the dangers involved in using certain chemicals. Figure 1 describes several common chemical warning signs.

Chemical Warning Signs (Figure 1)

Ignitable chemicals generally are liquids with flash points below 60°C or 140°F.

Reactive chemicals ignite or create poisonous vapors when mixed with other products or can explode when exposed to heat, air, water, or shock.

Corrosive chemicals are generally aqueous wastes with a pH less than or equal to 2.0 or greater than or equal to 12.5.

Toxic chemicals may cause long-term illness (such as cancer). Pesticides, paint thinners, many auto products, and some cleaners are toxic.

New Tool

Another common system for identifying chemical hazards is the U.S. National Fire Protection Association (NFPA) system. *NFPA chemical hazard warning labels* are attached to the containers with the chemicals. Although it looks simple, an NFPA label carries a lot of important information about a chemical. NFPA labels are color coded; each color on the label represents a different type of hazard. The system also uses a numerical rating system. Zero represents little to no danger, while a rating of four represents the greatest danger.

Figure 2 contains an example of a label from the NFPA system for the chemical diborane. According to the rating system, diborane is extremely flammable, reactive, and presents a serious health hazard.

National Fire Protection Association Chemical Label Example (Figure 2)

Blue = Health hazard
Red = Fire hazard
Yellow = Reactivity hazard
White = Special hazard

0 = Minimal hazard
1 = Slight hazard
2 = Moderate hazard
3 = Serious hazard
4 = Severe hazard

Examples of Hazardous Chemicals

EPA's National Partnership for Environmental Priorities (NPEP) Program has identified 31 chemicals and metals that are particularly hazardous to human health and the environment. NPEP is an EPA partnership program in which public and private organizations partner with EPA to reduce or discontinue the use of these 31 chemicals (for more information, see www.epa.gov/npep). Table 1 lists the 31 Priority Chemicals, which include organic compounds and metal compounds.

EPA'S List of 31 Priority Chemicals (Table 1)
Organic Compounds
1,2,4-Trichlorobenzene
1,2,4,5-Tetrachlorobenzene
2,4,5-Trichlorophenol
4-Bromophenyl phenyl ether
Acenaphthene
Acenaphthylene
Anthracene

EPA'S List of 31 Priority Chemicals (Table 1)
Benzo(g,h,i)perylene
Dibenzofuran
Dioxins/Furans*
Endosulfan, alpha & Endosulfan, beta*
Fluorene
Heptachlor & Heptachlor epoxide*
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclohexane (gamma-Lindane)
Hexachloroethane
Methoxychlor
Naphthalene
Pendimethalin
Pentachlorobenzene
Pentachloronitrobenzene (Quintozene)
Pentachlorophenol
Phenanthrene
Polycyclic Aromatic Compounds (PACs) / PAH Group (as defined in TRI)
Polychlorinated Biphenyls (PCBs)
Pyrene
Trifluralin
Metals and Metal Compounds
Cadmium
Lead
Mercury

** Considered one chemical on this list.*

Source: US EPA, National Partnership for Environmental Priorities, www.epa.gov/npep.

How to Learn More about Chemicals

Understanding the types of chemicals your business uses and the hazards associated with them is the first step to take when deciding how and where to eliminate chemical wastes. There are a variety of resources available for learning more about chemicals and their characteristics. Two important resources include Material Safety Data Sheets and a Pocket Guide to Chemical Hazards.

New Tool

Material Safety Data Sheets (MSDS) are an important resource and safety tool for workers who handle chemicals. MSDSs are designed to provide both workers and emergency personnel with the proper procedures for handling or working with a particular substance. The Occupational Health and Safety Administration (OSHA) requires that MSDS forms be available to all employees working with chemicals. MSDSs include information on physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill/leak procedures. These are of particular use if a spill or accident occurs. Appendix B contains a template for a Material Safety Data Sheet.

New Tool

Another tool for identifying and understanding hazardous chemicals is a pocket guide to chemical hazards issued by the National Institute for Occupational Safety and Health (NIOSH) of the Centers for Disease Control and Prevention (CDC). The *NIOSH Pocket Guide to Chemical Hazards* (NPG) is a source of general industrial hygiene information on several hundred chemicals for workers, employers, and occupational health professionals. The NPG does not contain an analysis of all pertinent data; instead it presents key information and data in abbreviated or tabular form for chemicals or substance groupings (e.g., cyanides, fluorides, manganese compounds) that are found in the work environment. The pocket guide includes the following information:

- NIOSH Recommended Exposure Limits
- Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits
- A physical description of the agent with chemical and physical properties
- Measurement methods
- Personal protection and sanitation recommendations
- Respirator recommendations
- Information on health hazards including route, symptoms, first aid, and target organ information

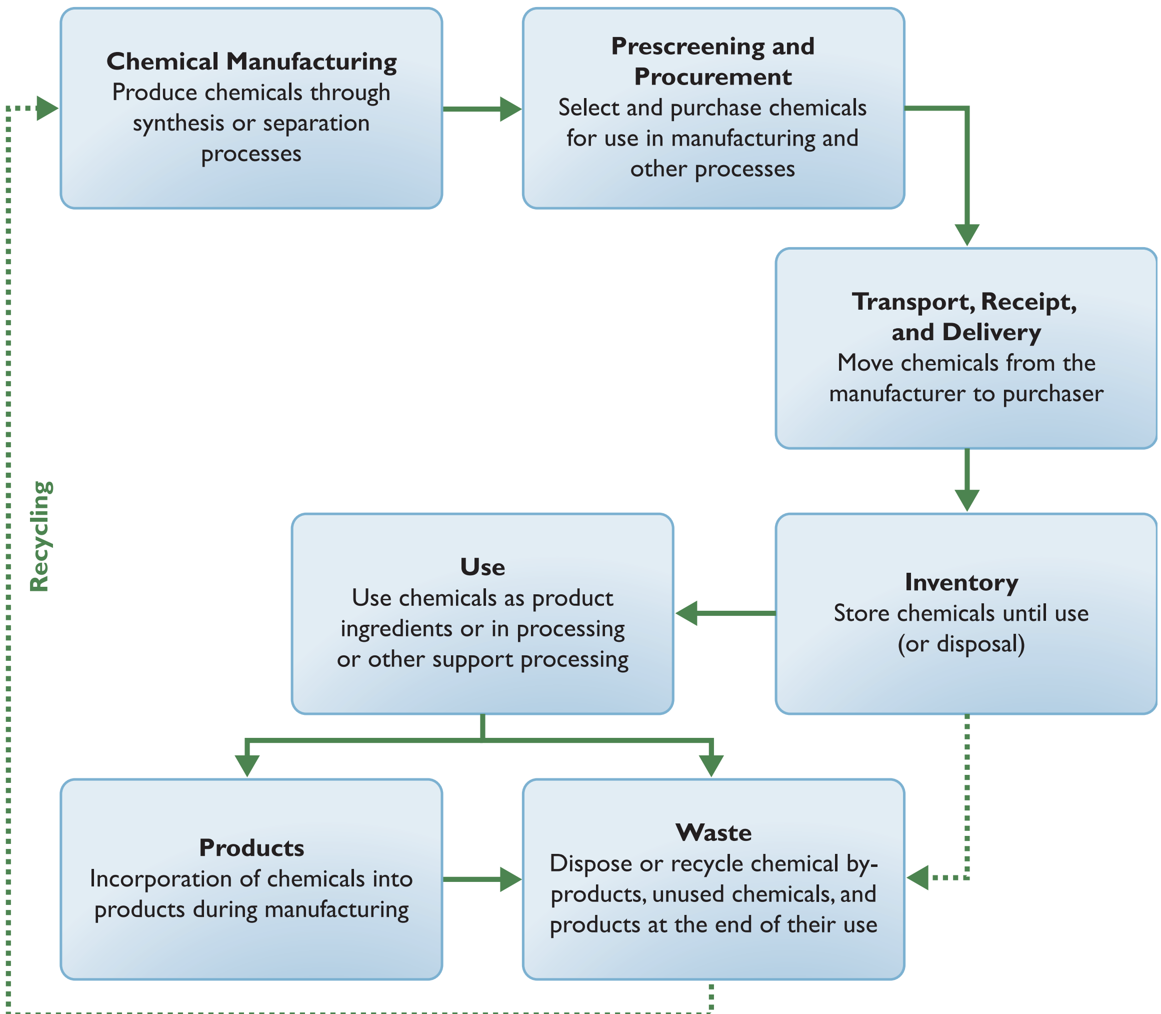
Appendix A describes additional chemical resources, including resources for identifying substitutes for hazardous chemicals. Furthermore, Chapter 6 (Lean Product and Process Design Methods) describes strategies and tools for designing products and processes that use less hazardous chemicals.

The Chemical Lifecycle

Key Term

The use of chemicals for production is just one part of the “lifecycle” of a chemical. The *chemical lifecycle* includes all the activities involved in the manufacturing, use, storage, disposal, and possible re-use of chemical substances. Figure 3 outlines the stages of the chemical lifecycle.

Chemical Lifecycle (Figure 3)



As with typical product "value streams" (which generally focus on the "use" or "manufacturing" steps), there are non-value added activities (wastes) associated with each step in the chemical lifecycle. The following chapters in this toolkit describe a variety of ways that Lean methods can be used to identify and reduce chemical wastes. Chapters 3, 4, and 5 focus on reducing wastes in the "inventory," "use," and "waste" stages of the chemical lifecycle. Chapter 6, with its focus on product design, covers strategies that affect multiple stages in the lifecycle, including chemical manufacturing and the selection of chemicals.

To Consider

- What types of chemicals does your facility use and/or produce?
- Are the chemicals well marked and easy to identify?
- Do you know the hazards associated with those chemicals?
- How much money does your facility spend purchasing chemicals? How much of those chemicals are thrown away before being used (e.g., if they expire or go off-specification)?
- How much money does your facility spend on hazardous wastes? (Consider costs for purchasing raw materials that end up in hazardous waste streams as well as costs to dispose of the wastes.)
- Who makes decisions involving chemical use at your company?

CHAPTER 3

Driving Out Chemical Waste with Lean Events

Lean events are critical for identifying wastes in a value stream and implementing process improvements to eliminate those wastes. This chapter describes strategies for reducing chemical wastes in the following two types of Lean events:

- Value Stream Mapping Events
- Kaizen Events

Value Stream Mapping Events

Key Term

Value stream mapping is a Lean method for creating a visual representation of the flows of information and materials (work in process) between all the activities involved in producing a product for a customer.[7] The power of value stream mapping lies in walking the plant floor, talking to workers, and closely observing how a product is actually made. Lean practitioners use value stream mapping to:

- Identify major sources of non-value added time in a value stream (depicted on a "current state" map);
- Envision a less wasteful future state (often shown on a "future state" map and/or an "ideal state" map); and
- Develop an implementation plan for future Lean activities, including kaizen events to improve specific processes in the value stream.

Key Point

Involving people (internal staff or external experts) with environmental health and safety (EHS) expertise in value stream mapping is one of the most effective ways to enhance your facility's Lean and environmental performance. Consider inviting EHS staff at your facility to value stream mapping events to identify additional sources of waste in the value stream, quantify environmental wastes and costs associated with processes, and offer outside perspectives on potential process improvement opportunities.

With some minor additions, value stream maps can become powerful tools for learning to see chemical wastes—how chemicals can affect time, quality, and cost. Two strategies for incorporating chemicals into value stream mapping are described below:

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7 See Appendix A of EPA's *Lean and Environment Toolkit* (http://www.epa.gov/lean/toolkit/app-a.htm) for more information about value stream mapping.

- Adding chemical metrics to value stream maps
- Examining key environmental inputs and outputs in value stream maps

See Chapter 3 of EPA's *Lean and Environment Toolkit* (www.epa.gov/lean/toolkit/ch3.htm) for additional strategies for reducing environmental wastes using value stream mapping.

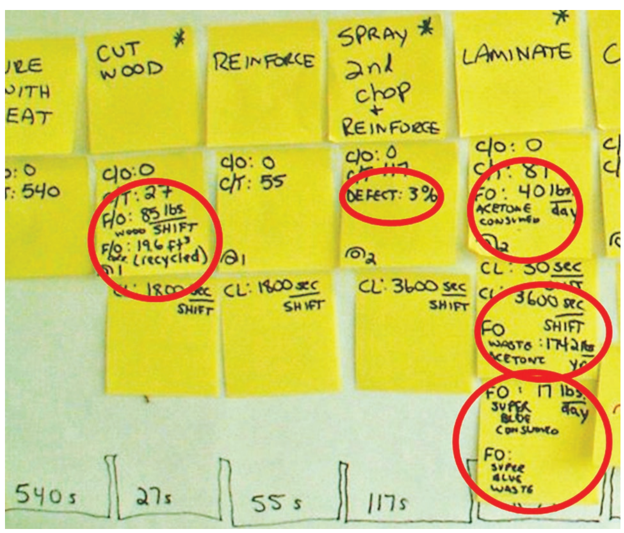
Add Chemical Metrics to Value Stream Maps

Although the most common metrics on value stream maps relate to time (e.g., cycle time, changeover time, value added time, and non-value added time), the data boxes in value stream maps can also record other key data for each process, such as environmental wastes and costs.

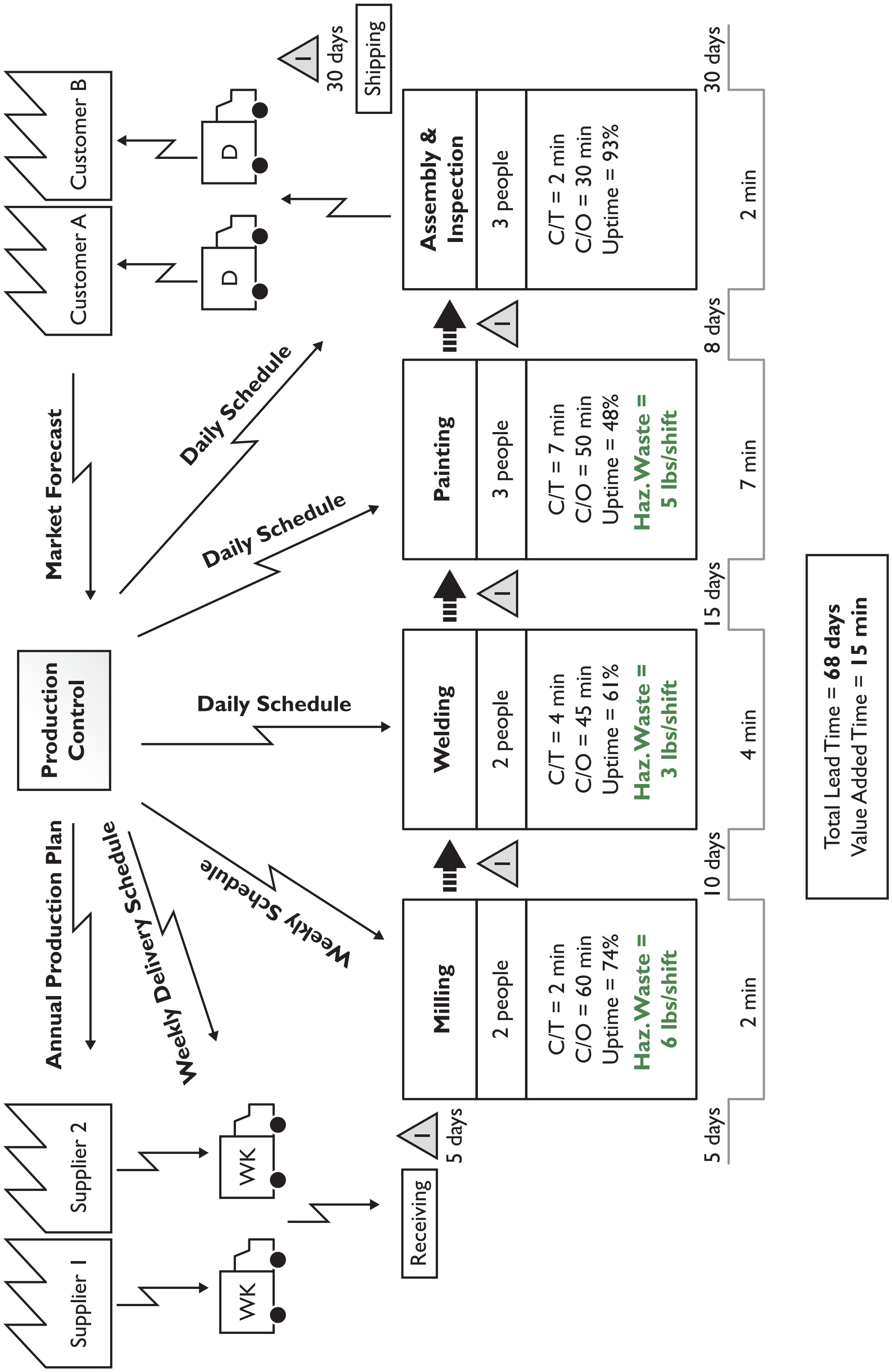
New Tool

Add chemical waste information to process data boxes on the current state value stream map to analyze and record how much waste is generated at each process. For example, you could record the amount of hazardous waste generated by a process over a certain time period (e.g., per shift), or you could quantify the costs associated with those wastes. Be sure to include the cost of purchasing the raw materials, time spent managing the wastes, and disposal costs. Figure 4 shows process data boxes with environmental waste included (labeled "FO" for "fallout" wastes in this example). Figure 5 shows an example of a current state value stream map with chemical metrics included.

Process Boxes Showing Environmental Wastes (Figure 4)



Current State Map with Chemical Metrics (Figure 5)



When chemical metrics are integrated into the current state map along with other Lean metrics, the team conducting the value stream mapping event can use those data to see a more complete picture of the wastes in the value stream and the potential for improvement opportunities. That is, the chemical data can inform the development of a future state map for the value stream and an implementation plan to achieve that future state. *Consider identifying at least one kaizen event that targets a large source of chemical waste*.

Key Point

Chemical wastes can occur in many parts of the value stream. Too much chemical inventory could lead to expired or off-spec chemicals that require disposal. Excess use of chemicals beyond what adds value from the customer's perspective and improper use of chemicals (e.g., incorrect mixing) in processes also result in waste. In the chemical manufacturing industry, key sources of waste include chemical reactors, separations, and other process equipment. For example, many chemical reactors require a lot of reactant feed and/or reaction conditions that are crucial to producing the product. Chemical reactors often require precise control of many inputs. If reactant feeds or operating conditions deviate from target values, the process yield may suffer or "off-spec" products may be produced, both of which will likely lead to increased waste.

Examine Key Environmental Inputs and Outputs in Value Stream Maps

Another way to examine environmental wastes in value stream mapping events is to record the key resource "inputs" to each process (e.g., raw materials, energy, and water use) and the key non-product "outputs" that result from each process (e.g., scrap, air emissions, hazardous waste, etc.) directly onto value stream maps. *Use different colored lines to show resource flows and waste flows out of each process data box on the value stream map*. In the chemical context, inputs would include chemicals used in the process and non-product outputs would include any hazardous wastes generated (e.g., hazardous chemicals mixed with other materials). Figure 6 provides a conceptual outline of how to add resource input and waste output lines to process maps, while Figures 7 and 8 depict full value stream maps incorporating the input and output lines.

New Tool

Conceptual Outline of Adding Environmental Inputs and Outputs on Value Stream Maps (Figure 6)

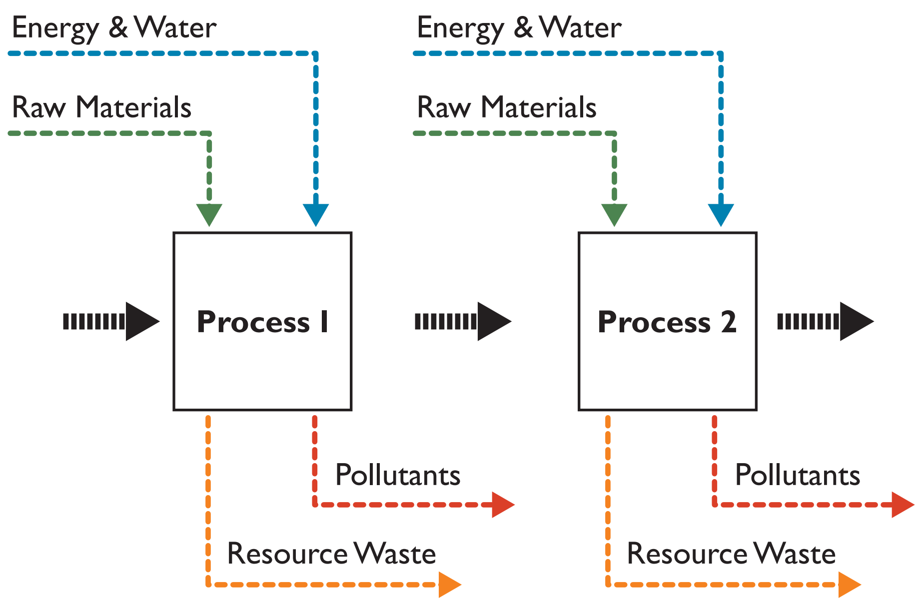
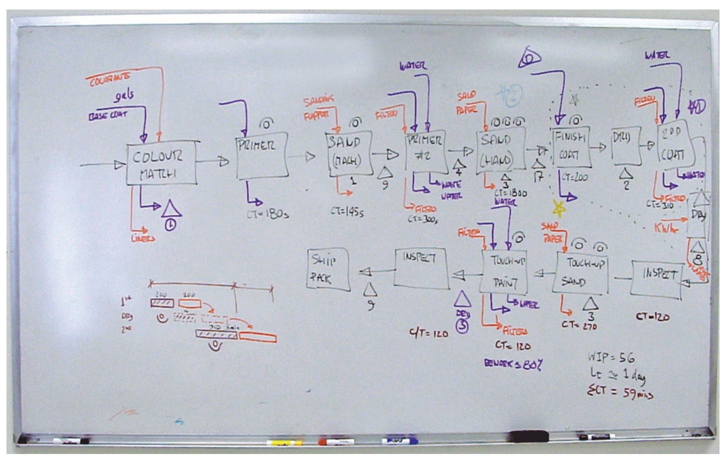
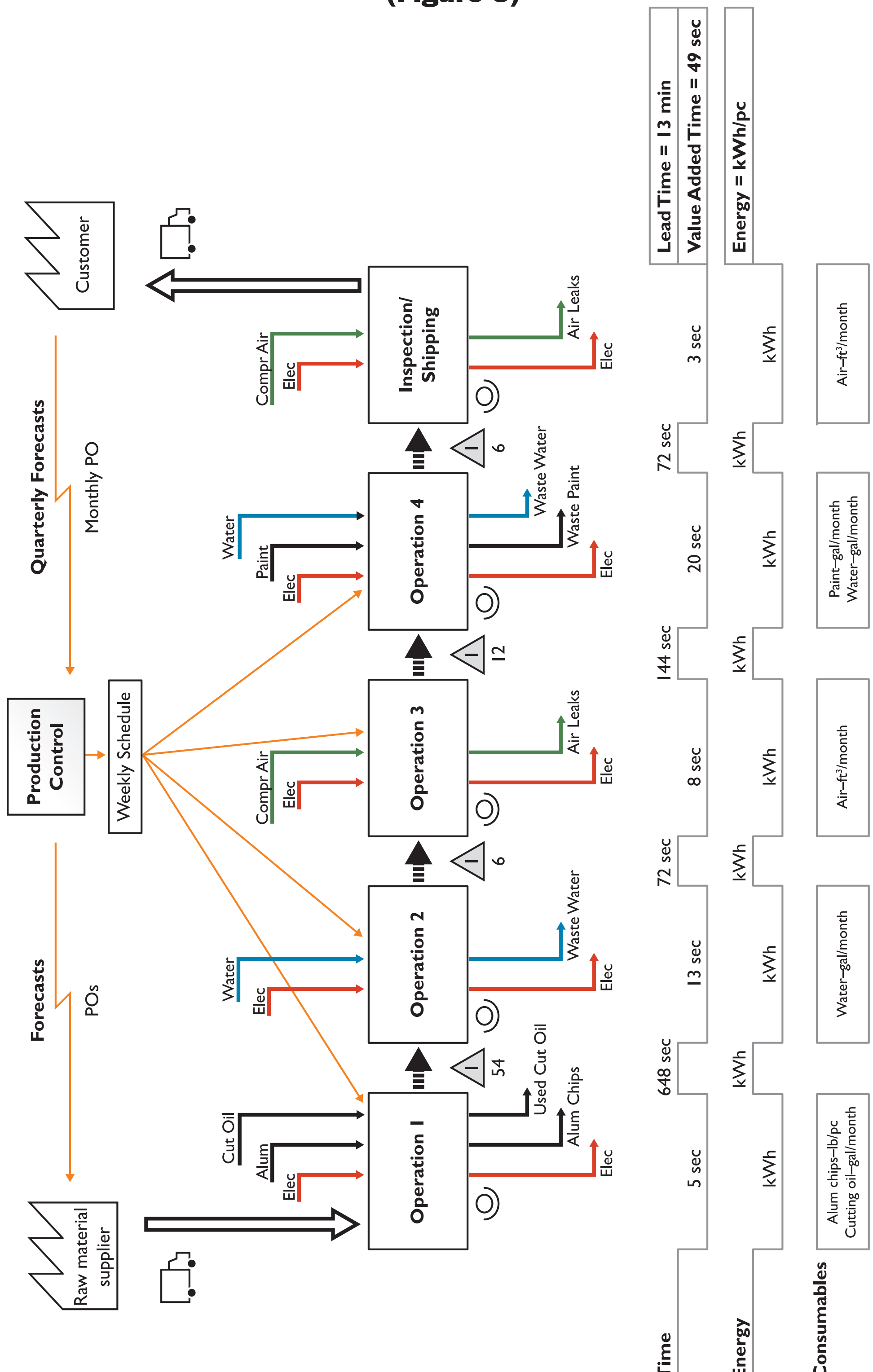


Photo of Modified Value Stream Map (Figure 7)



Value Stream Map Incorporating Environmental Inputs and Outputs (Figure 8)



Source: This figure is based on a Lean and environment value stream map developed by the Oregon Manufacturing Extension Partnership, www.omep.org.

This method combines concepts of traditional Lean value stream mapping with the materials flow process mapping used by pollution prevention (P2) experts. Although the resulting value stream map could look complicated, it can be very powerful to see the Lean and environmental wastes together on a single map. Detailed hierarchical process mapping of environmental inputs and outputs can also supplement value stream maps and/or be developed and used in kaizen events to improve specific processes. See Chapter 4 (Kaizen Events) of EPA's *Lean and Environment Toolkit* for more information about hierarchical process mapping.

Value Stream Mapping at Woodfold Manufacturing, Inc. (Box 6)

- ✓ In 2007, Woodfold Manufacturing, Inc., a manufacturer of custom wood products located in Forest Grove, OR, participated in a Lean and environment project with Oregon Manufacturing Extension Partnership (OMEP) and the Pollution Prevention Resource Center (PPRC).
- ✓ OMEP facilitated a value stream mapping event that targeted a shutter painting line, while PPRC and Woodfold staff provided environmental expertise. The event addressed chemical use and hazardous wastes associated with painting, along with other environmental impacts.
- ✓ The project team closely scrutinized the process, noted environmental inputs and outputs on the process boxes on the value stream map, and identified potential future Lean and environmental improvements.
- ✓ Woodfold implemented many of the improvement opportunities identified in the event, and achieved the following results:
  - Saved about $44,800 per year, including $34,700 per year from improvements to paint spray transfer efficiency.
  - Found a local recycler for PVC scrap, diverting 6 tons per year of solid PVC waste from the landfill.
  - Reduced volatile organic compound (VOC) emissions by nearly 1,000 lbs per year.

Source: Correspondence with Kevin Emerick, EHS Manager at Woodfold Mfg., and PPRC, "Lean Green Manufacturing Case Study: Woodfold Mfg., Inc.," 2007, www.pprc.org/solutions/woodfoldcasestudy_12_07.pdf.

Kaizen Events

Key Term

Kaizen is a combination of two Japanese words meaning "take apart" and "make good;" kaizen refers to the philosophy of continual improvement. *Kaizen events*—also known as rapid process improvement events—are a team activity designed to eliminate waste and make rapid changes in the workplace in a 2–5 day period.[8] They are a primary means of implementing other Lean methods, such as standard work, 5S (or 6S), one-piece flow, and customer-driven "pull" production.

Know When to Seek Environmental Health and Safety Expertise in Kaizen Events

One of the most important ways to reduce chemical wastes and avoid potential regulatory issues is to involve staff with EHS expertise in planning for and conducting kaizen events on environmentally sensitive processes. In particular, if there's someone at your organization who specializes in chemicals and hazardous waste management, consider inviting that person to participate in value stream mapping events or kaizen events targeting processes that deal with chemicals. Box 7 lists several processes with the potential for significant chemical wastes.

Processes with Chemical Wastes (Box 7)

1. Bonding and sealing
2. Chemical and hazardous materials management
3. Chemical manufacturing
4. Cleaning and surface preparation
5. Metal fabrication and machining
6. Metal finishing and plating
7. Painting and coating
8. Waste management
9. Welding

New Tool

Many types of Lean events would benefit from EHS staff involvement, especially during the planning phase, to avoid potential regulatory compliance issues and identify additional waste-reduction opportunities. Use the list of *Common Operational Changes That Trigger EHS Involvement* below as a guide for when to seek additional EHS expertise for Lean events. If EHS staff participated in the value stream mapping event to select Lean implementation priorities, your team should have a good idea of which events would benefit from EHS expertise.

[8] See Appendix A of EPA's *Lean and Environment Toolkit* (http://www.epa.gov/lean/toolkit/app-a.htm) for more information about kaizen events.

Common Operational Changes That Trigger EHS Involvement (Box 8)

- ✓ Changes to the type, volume, or introduction/issuance procedure for chemicals/materials used by employees. **Affects chemical exposure, regulatory compliance, and reporting needs.**
- ✓ Changes to the nature, concentration, or volume of waste generated by a process, including all media such as air emissions, water discharges, and liquid and solid waste. **Affects compliance with regulatory and permitted limits, as well as pollution control and management capacity.**
- ✓ Changes to the physical layout of the processes (e.g., moving work or storage areas), to equipment and technologies used, or to the facility (e.g., moving, replacing, or installing vent hoods, stacks, floor drains or process tanks). **Affects compliance with regulations and permits, as well as work practice requirements.**

Caution

If not properly conducted, these types of operational changes could harm the health and safety of workers, or cause violations of EHS regulations. For example, moving hazardous waste collection areas from central locations to work cells could affect compliance with waste management regulations (e.g., Resource Conservation and Recovery Act regulations).[9] Similarly, replacing existing air pollution control equipment with new right-sized equipment would require permit modifications under the Clean Air Act.

New Tool

For a more formal system for identifying when to involve EHS experts in Lean events, use the *Lean Event EHS Checklist* included in EPA's *Lean and Environment Toolkit* (the checklist is available at www.epa.gov/lean/toolkit/app-c.htm). Requiring team leaders to complete this form helps ensure that Lean teams involve EHS staff in Lean events when appropriate.

[9] See the disclaimer on page ii regarding the definitions of wastes used in this toolkit.

Identify Chemical Wastes in Kaizen Events

New Tool

All kaizen event participants can help to identify chemical wastes in processes. Use the *Key Questions for Identifying Chemical and Hazardous Waste Reduction Opportunities* below as a guide.

Key Questions for Identifying Chemical and Hazardous Waste Reduction Opportunities (Box 9)

Chemicals Use

- ✓ What types and in what quantities are chemicals used in the process?
- ✓ How can you reduce the overall amount of chemicals used?
- ✓ Can you switch to less harmful chemicals?
- ✓ How can you reduce the number of chemicals used?
- ✓ Can you eliminate any non-value added use of chemicals from the product or process (unneeded painting, etc.)?
- ✓ Is there an effective way to meet customer needs without chemicals? For example, can metal fasteners be used instead of chemical adhesives?

Hazardous Waste

- ✓ What types and quantities of hazardous waste are generated by the process?
- ✓ How can you reduce the amount of hazardous waste generated?
- ✓ Can you better isolate and separate hazardous wastes from other wastes?
- ✓ Can you find opportunities to reuse or recycle any chemicals or hazardous wastes?

Environmental health and safety professionals and technical assistance providers can support kaizen event teams by researching chemicals used in the process, identifying less hazardous chemicals that could be used as alternatives, and finding sector-specific resources and tools for reducing chemical wastes. Appendix A describes several resources that can help reduce chemical wastes and identify safer alternatives to hazardous chemicals; the Appendix also lists non-profit technical assistance providers, as well as general resources about chemicals.

Key Point

Asking "why" five times is a useful strategy for identifying the root causes of wastes. This approach often reveals simple solutions to eliminate wastes that save time, cut costs, and improve the quality of the process. Box 10 describes an example of how the five whys technique can identify causes of chemical wastes.

Asking Why Five Times (Box 10)

Asking "why" five times is a simple way to identify the root cause of a waste, and that makes it easier to identify ways to reduce or eliminate the waste. Here is an example:

- **Why is the solvent a waste**? Because the solvent is contaminated with oil.
- **Why is it contaminated with oil**? Because the solvent was used to clean oil off the parts.
- **Why are the parts oily**? Because the manufacturer puts a coating of oil on them before shipping them to this facility.
- **Why does the manufacturer put a coating on them**? To prevent the parts from corroding after manufacture.
- **Why is this type of corrosion protection absolutely necessary**? We don't know any other ways to protect the parts from corrosion. Let's form a team to identify and test some alternatives.

In this example, the root cause of solvent waste is corrosion protection. There may be other ways to achieve that objective without using oil.

Source: Arizona Department of Environmental Quality, *Pollution Prevention Analysis and Plan Guidance Manual*, March 2006, www.azdeq.gov/environ/waste/p2/download/first.pdf.

Canyon Creek Cabinet Company "Toxics Team" (Box 11)

✓ Canyon Creek Cabinet Company—a large manufacturer of custom frameless and framed cabinetry based in Monroe, WA—worked with the Washington State Department of Ecology and Washington Manufacturing Services in a Lean and Environment Pilot Project to evaluate the benefits of integrating environmental tools into Lean.

✓ A cross-functional project team called the "Toxics Team" conducted a value stream mapping workshop and three kaizen events on the finishing department, where products are stained and coated.

Stain Booth, Before the Project

Stain Booth, After the Project

✓ The Team analyzed environmental wastes alongside other production wastes, and implemented process changes that improved process efficiency, cut costs, and reduced wastes.

✓ The company is saving $1 million per year from the project. The chemical-related results were impressive:

- Reduced hazardous substances used by 68,700 lbs per year by installing dedicated pumps for each solvent-based stain color.
- Decreased hazardous wastes by 84,400 lbs per year by reducing wastes from changeover of aqueous and solvent-based stains.
- Cut volatile organic compound (VOC) emissions by 55,100 lbs per year, primarily by employing a new unicoat product to replace the existing sealant and topcoat. These changes allowed the facility to increase production capacity up to 70 percent before reaching the Clean Air Act Title V threshold for VOCs.

For more information about the project, see the Washington State Department of Ecology's Lean and Environment website, www.ecy.wa.gov/programs/hwtr/lean.

Conduct Chemical-Focused Kaizen Events

Key Point

To really drive out chemical wastes at your facility, *conduct kaizen events that focus specifically on eliminating chemical wastes*. As a starting place, use value stream maps and/or other information to identify processes that generate large quantities of hazardous wastes. Then harness the power of a cross-functional team of employees in a kaizen event to identify and implement process changes to reduce those wastes. In the longer term, consider redesigning processes so that they do not require hazardous chemicals as inputs. Box 11 above describes an example of a Lean and environment project that focused on reducing chemical wastes, along with other Lean wastes.

To Consider

- What processes use the most chemicals, or the most toxic chemicals at your facility? What steps would you take to find out?
- Do you know which processes generate the most hazardous waste at your facility? What steps would you take to find out?
- What ideas do you have for reducing chemical wastes?
- Have you invited Environmental Health and Safety personnel to participate in Lean events?
- Is there a specific process at your facility that uses large amounts of chemicals that you could target in a chemical-focused kaizen event?
- Is there a process at your facility that uses a particularly toxic chemical that you could target in a chemical-focused kaizen event?

CHAPTER 4
Chemical Management in the Lean Organization

Chemical use and management can look very different in a Lean organization, when compared with a conventional manufacturing setting. This chapter describes the following:

- Lean Strategies and Chemical Use
- Lean Approaches to Chemical and Hazardous Waste Management

Lean Strategies and Chemical Use

Classic Lean manufacturing strategies typically involve the conversion from batch-and-queue production with large material inventories to right-sized manufacturing cells with one-piece flow and just-in-time material delivery. This fundamental reconfiguration of production activities has major consequences—and improvement opportunities—for chemical use and management.

In this context, four Lean strategies can be used to dramatically reduce chemical use, waste, and risk while supporting core Lean goals. These include cellular manufacturing and right-sized equipment, just-in-time delivery, right-sized containers and kitting, and point-of-use storage.

Cellular Manufacturing and Right-Sized Equipment

Key Term

Cellular manufacturing refers to the arrangement of production work stations and equipment in a sequence that supports a smooth flow of materials and components through the production process with minimal transport or delay. Rather than processing multiple parts before sending them on to the next machine or process step (as is the case in batch-and-queue, or large-lot production), cellular manufacturing aims to move products through the manufacturing process one-piece at a time, at a rate determined by customers' needs.

Key Term

To make the cellular production work, an organization must often replace large, high volume production machines with small, flexible, *right-sized equipment* and machines to fit well in the cell. Using this approach, production capacity can be incrementally increased or decreased by adding or removing production cells.

Key Point

The conversion to cellular manufacturing and right-sized equipment can dramatically reduce the amount of chemicals used in a production process. First, one-piece flow of products through the process minimizes overproduction and enables workers to catch defects quickly, limiting chemical use to amounts needed to meet customer needs.

Second, right-sized equipment typically requires only a fraction of the chemical inputs of conventional equipment. Conventional manufacturing equipment is often over-sized to accommodate the maximum anticipated demand. Since purchasing a new large piece of equipment is often costly and time-consuming, engineers often design in additional buffer capacity to be sure that the equipment does not bottleneck production. Conventional, oversized equipment can lead a company to use significantly more chemicals than needed to get the job done. For example, a facility with one large, 1000-gallon part cleaning and degreasing tank may only wash a few small parts in each batch. A shift to much smaller, 10-gallon, right-sized parts cleaning tanks may be all that is needed to get the actual work done, saving hundreds of gallons of chemicals.

Just-in-Time Delivery

Key Term

Key Term

Just-in-time (JIT) delivery refers to an inventory strategy implemented to reduce in-process inventory and its associated carrying costs by coordinating material deliveries to better align with process consumption. Applying JIT to chemical management typically means that fewer chemicals are stored on-site, and that chemical suppliers deliver chemicals more frequently in smaller batches. In a JIT system, the need for a delivery is typically signaled by actual use of a material. The signaling system, called *kanban* in Japanese, can involve electronic messages, note cards, or reusable containers that tell suppliers more materials are needed. In practice, some buffer inventories may be kept to insulate against spikes in demand or to ensure adequate supplies of difficult to procure materials.

Key Point

JIT creates opportunities for reducing chemical risk and wastes. Small chemical inventories can significantly reduce the volume of chemicals that must be stored on-site. This has several advantages:

- Lower likelihood of a large chemical spill or accident
- Reduced need to purchase and maintain chemical storage tanks
- Reduced space needed for storing chemical inventories
- Reduced need for chemical spill prevention equipment and measures
- Elimination of certain regulatory, permitting, and reporting requirements, including the need to develop and implement Risk Management Plans required by Section 112(r) of the Clean Air Act (see example in Box 12)

Eliminating the Need to Address Risk Management Planning Requirements – Goodrich Aerostructures Example (Box 12)

- ✓ Goodrich Aerostructures facilities in California shifted to Lean point-of-use chemical management systems to eliminate wasted worker movement and downtime. As an additional benefit, these shifts reduced chemical use and associated hazardous waste generation.
- ✓ At one California plant, the just-in-time chemical management system enabled Goodrich Aerostructures to eliminate four 5,000 gallon tanks containing methyl ethyl ketone, sulfuric acid, nitric acid, and trichloroethane.
- ✓ As a result, the potential for large-scale spills associated with these tanks, as well as the need to address risk management planning and other chemical management requirements for these tanks under Section 112(r) of the Clean Air Act were eliminated.

Small chemical inventories can also reduce the amount of chemicals that enter a facility's hazardous waste stream without ever being used. It is easier for chemicals in large on-site inventories to expire, go out of specification (become obsolete), or be contaminated before use. This poses a significant cost burden, as an organization pays to purchase, store, and dispose of chemicals without deriving any value from them. Some organizations have found that prior to moving to JIT chemical deliveries, as much as 40 percent of their chemical inventories were being sent to their hazardous waste stream without ever being used.[10]

While moving to JIT chemical deliveries can increase the per-unit cost of chemical purchases, many organizations find that the total system cost advantages are significant, driven by the benefits discussed above.

Right-Sized Containers and Kitting

Key Term

Right-sized containers offer an important Lean chemical management strategy. Right-sized containers are typically associated with "unit of use ordering," which involves purchasing chemicals in quantities and packaging that makes it easy to use them in a manufacturing cell or Lean workspace. Right-sized containers can also limit the amount of a chemical that may expire or become unusable due to contamination or spoilage. Right-sized containers, which are often reusable, can be used to limit the need to transfer materials from larger cribs or containers into smaller ones, reducing potential for spills. A potential environmental tradeoff with right-sized containers, however, is that there can be additional packaging waste. In some cases, it may be

[10] U.S. EPA, "Lean Manufacturing and the Environment," October 2003, www.epa.gov/lean/leanreport.pdf, p. 25.

useful to consider purchasing chemicals in bulk to eliminate excessive packaging, especially if the packaging is considered hazardous wastes, or to look for alternative solutions to eliminate the wastes.

Right-Sized Containers (Figure 9)

Key Term

Kitting is a technique that involves the gathering of all the parts and materials needed for a particular manufacturing or assembly process step and issuing the kit to the manufacturing line at the right time and in the right quantity. Kitting is sometimes viewed as a waste in the Lean context, as it may require excessive material handling that could be better accomplished through the use of kanban and point-of-use storage (see below). *Kitting can be particularly useful, however, in right-sizing chemicals needed in a production process, particularly when right-sized containers are not available*. Kitting can prevent the excess use or over-mixing of chemicals by only providing chemicals in the amount needed to do the job. For example, kitting of chemical adhesives can improve the consistency of the amount and quality of adhesives used, while eliminating the need to dispose extra adhesives as hazardous waste.

Key Point

Point-of-Use Storage

Key Term

Point-of-use storage (POUS) refers to the storage of small amounts of inventory in right-sized containers at the point in a manufacturing process where the materials are used—such as in or near a manufacturing cell. POUS typically involves a shift away from large, centralized stockrooms. POUS stations and cabinets are particularly useful for getting smaller parts and smaller volumes of chemicals and materials to the point of use. In some Lean organizations, material handlers known as *water spiders* travel around a facility to keep POUS stations and cabinets stocked sufficiently to meet short-term production needs. Other organizations opt to have vendors or suppliers directly stock POUS stations throughout a manufacturing facility on a routine basis.

Key Term

POUS systems dramatically reduce the time and walking distance employees must devote to obtaining chemicals and materials needed for their work. POUS systems can also substantially

Key Point

reduce overall material handling and support costs at a facility. *POUS systems support efforts to reduce chemical use and wastes by supporting JIT chemical delivery strategies*. POUS stations and cabinets provide a mechanism for efficiently getting right-sized containers and kits to where they are needed, reducing both the amount of chemical used and the amount of chemicals entering hazardous waste streams.

Caution

If not implemented properly, POUS systems can lead to potential regulatory issues or create unnecessary hazards to worker health and safety. See Chapter 5, Managing Chemicals in Lean Workspaces, for best practices for POUS systems as well as additional information on the set up, organization, and visual management of POUS stations.

Point-of-Use Storage Cabinets at Robins Air Force Base (Box 13)

- ✓ Robins Air Force Base (AFB), a depot for repairing aircraft and producing spare parts located in Georgia, has implemented Lean since May 1999. Environmental safety and occupational health (ESOH) staff have participated in or led many rapid process improvement events.
- ✓ Robins AFB instituted a point-of-use (POU) cabinet system for storing chemicals in "right-sized" quantities close to where they are used. Robins AFB personnel stock the cabinets with a two-day supply of chemicals and monitor them daily. There are hazardous waste disposal areas near the cabinets to facilitate proper disposal. The POU system was instituted after ESOH staff led a kaizen event that incorporated visual management controls and 6S (5S + Safety) techniques.
- ✓ Robins AFB has about 180 point-of-use cabinets installed in many areas of the base. Employees must complete point-of-use request forms to have a new POU cabinet installed. ESOH staff review the POU request forms and inspect each POU cabinet.
- ✓ By implementing the POU cabinets and distributing "right-sized" quantities of chemicals, Robins AFB achieved the following results:
  - Decreased hazardous chemical use and hazardous waste generation by 20 percent on the flight line.
  - Decreased hazardous chemical use and hazardous waste generation by 50 percent in one shop.
  - Reduced worker travel to retrieve chemicals by 1,500 miles.

Lean Approaches to Chemical and Hazardous Waste Management

Lean thinking and methods can also transform how an organization approaches chemical and hazardous waste management. First, some companies have turned to their supply chain or external partners for strategic chemical and waste management services. By "servicizing" chemical procurement, some Lean companies have increased focus and incentives for eliminating the non-value-added aspects of chemical use. Second, some companies have used Lean methods, such as value stream mapping and kaizen events, to directly improve chemical and waste management work processes.

Chemical Management Services

Key Term

Chemical management services (CMS) is a business model in which a customer purchases a chemical service, rather than a chemical product. Chemical management service contractors support an entire system for managing chemicals and chemical wastes. For example, if a company needs a chemical to remove paint, it can contact a chemical management service provider who will not only provide a chemical to remove paint but they will also deliver it, track inventory and MSDS information, implement process efficiency improvements, collect data for environmental reporting, and recycle or dispose of chemicals. Chemical management services can encompass all areas of the chemical lifecycle from manufacturing to disposal and recycling (See Figure 3, Chemical Lifecycle). By applying a chemical management service approach, a company can reduce the costs and risks associated with those chemicals.

Key Point

Cost reduction is usually a key reason for applying CMS. According to research conducted by the Chemical Services Partnership, *the cost of traditional chemical management can range from $1 to $3 for every dollar of chemical purchased*.[11] For example, if a facility spends $1 million to purchase chemicals, it will have to spend an additional $1 million to $3 million to manage those chemicals. These high costs can be attributed to activities associated with chemical use, such as compliance, safety, disposal, and floor space. By applying CMS, a manufacturer can bundle all of its chemical needs into one service, which ultimately helps the manufacturer use chemicals more effectively and efficiently. CMS providers accomplish this by providing a company with the most appropriate quantities of chemicals. In addition, a CMS system has numerous other benefits including reducing emissions, wastes, accidents, and liabilities (see Box 14 for more CMS benefits).

[11] Chemical Services Partnership, "What is CMS," www.chemicalstrategies.org/implement_whatiscms.htm, accessed 3/17/09.

Benefits of Chemical Management Services (Box 14)

CMS approaches can have several benefits, including:

- ✓ Creating a strong incentive for the service provider to reduce chemical use and cost per unit of value added, as well as to maximize and recapture the end-of-life value of recycled or used chemicals
- ✓ Allowing the customer to focus on its primary areas of business
- ✓ Shifting the responsibility for maintenance and ultimate disposal of chemicals to the supplier
- ✓ Increasing knowledge of chemical products, liabilities, and waste reduction opportunities by contracting with chemical specialists
- ✓ Elevating the role of the chemical vendor to realize its value as a partner, problem-solver, and information resource

Applying Lean Methods to Chemical and Waste Management

Some companies have focused Lean value stream mapping and kaizen events specifically on chemical and hazardous waste management support processes. Lean events can be used to streamline and improve a variety of EHS support functions that relate to chemicals and hazardous waste, including:

- Chemical selection and procurement processes
- Chemical handling and inventory management
- Management of Material Safety Data Sheets
- Chemical handling and hazardous waste training activities and tracking
- Hazardous waste labeling, manifesting, and recordkeeping procedures

Chemical and Hazardous Waste Management Process Improvement at Lockheed Martin (Box 15)

Lockheed Martin's Manassas, Virginia facility manufactures sonar systems for defense applications and has applied Lean and Six Sigma to non-traditional (low volume, high customization) manufacturing, research, and support activities. In 1995, managers began applying "Lean thinking" to restructure and improve Chemical, Environmental, Safety, and Health (CESH) operations and business processes.

The facility has used Lean and Six Sigma methods to implement a just-in-time chemical management system, where chemicals are delivered three times each week in "right-sized" containers to meet real-time demand. The new system eliminated the chemical warehouse, replacing it with point-of-use storage cabinets and right-sized containers of chemical supplies. The facility also used Lean and Six Sigma to reduce hazardous waste management system costs. This was accomplished by eliminating on-site treatment and the need for the RCRA Part B permit by shifting to regular hazardous waste pick-up by a waste management vendor.

Using Lean, Lockheed Martin achieved the following results:

- ✓ Moved from a fully permitted hazardous waste management facility to a generator with only short-term waste accumulation, significantly reducing regulatory compliance costs.
- ✓ Eliminated the chemical warehouse, reducing chemical storage space from 64,000 to 1,200 square feet.
- ✓ Virtually eliminated hazardous waste from chemicals expiring on shelf and mixed in quantities larger than needed.

For more information about the project, see the Lockheed Martin case study on EPA's Lean and Environment website, www.epa.gov/lean/studies/lockheed.htm.

Lean events can drive waste and inefficiencies out of chemical and hazardous waste management support processes, as illustrated in Box 15. Other Lean tools, such as Total Productive Maintenance (TPM), standard work, and visual controls, can ensure efficient and safe management of chemicals and waste on an on-going basis. These Lean tools are explored in Chapter 5.

To Consider

- What Lean strategies and methods are being used in your company? Is your facility shifting to manufacturing cells, right-sized equipment, and just-in-time delivery of inputs?
- How has implementation of these Lean strategies affected the total amount of chemicals used at your facility?
- Would using just-in-time delivery, right-sized containers, and/or kits improve how you manage and use chemicals at your facility?
- What chemical and hazardous waste management processes could be targeted with Lean events at your facility?

CHAPTER 5
Managing Chemicals in Lean Workspaces

Lean tools can also be used to improve the routine management of chemicals and hazardous wastes in Lean workspaces, cutting costs and enhancing safety. This chapter examines the following topics:

- Point-of-Use Storage (POUS) Best Practices
- Lean visual and workplace management tools, including 6S (5S + Safety), visual controls, standard work, and total productive maintenance

Point-of-Use Storage Best Practices

POUS chemical management systems can play a powerful role in reducing chemical use and wastes in a Lean workplace. POUS can also create significant challenges for worker health and safety and regulatory compliance without careful and sustained attention. This section discusses several ideas, and best practices, for implementing successful POUS systems that effectively reduce chemical wastes and risk, including POUS approval processes, POUS organization and set-up, and POUS maintenance and housekeeping.

Point-of-Use Storage Approval Processes

Caution

The roll-out and expansion of POUS systems involving chemicals must be carefully managed to protect worker health and safety and to avoid regulatory compliance violations. Numerous regulatory requirements may apply to a POUS station, depending on the type and amount of chemicals stored there. Examples of regulatory requirements that may be applicable to POUS stations include:

- Emergency Planning and Community Right-to-Know Act (EPCRA) requirements designed to ensure that workers and emergency responders are aware of chemical hazards in the workplace
- Resource Conservation and Recovery Act (RCRA) requirements designed to ensure hazardous wastes are appropriately managed by trained personnel
- Clean Air Act (CAA) air toxics standards and requirements designed to ensure that toxic chemical releases to the air do not adversely affect human health and the environment

- Occupational Safety and Health Administration (OSHA) and National Fire Protection Association (NFPA) requirements to protect worker health and safety from chemical hazards
- Local building and fire code requirements to prevent and contain fires and accidents

Regulatory Compliance under a Lean Chemical Management Strategy (Box 16)

Changes in chemical management under Lean have important consequences for how a facility ensures compliance with environmental regulations. Decentralization of chemical storage and use throughout a facility can pose interesting regulatory challenges. Careful consideration—and involvement of EHS personnel—is needed to align compliance management strategies with Lean chemical management activities. Examples include:

- ✓ Satellite accumulation area requirements for regulated hazardous waste
- ✓ Secondary containment requirements
- ✓ Air pollution control for right-sized equipment and chemical use
- ✓ Waste water control and management in manufacturing cells

Key Point

Facility EHS personnel should be involved in the process for reviewing and approving the establishment and siting of new POUS stations and cabinets to ensure that applicable environmental and safety regulatory requirements are identified and addressed. An organization should have a clear policy and set of procedures for requesting and approving the installation of a POUS station or cabinet.

New Tool

A POUS Request Form can be helpful to establish a clear process for fielding POUS requests and ensuring that applicable requirements are identified and addressed prior to implementation.

It can be useful to include the following information on a POUS Request Form:

- Information about the POUS requester
- Information on the party responsible for the POUS station
- The location of desired POUS station
- A list of chemicals that will be kept in the POUS, including relevant chemical numbers and codes, associated work process codes, and quantities/volumes

- A checklist or list of questions to ensure that required procedures are considered and followed (see Box 17 for example questions)
- Routing and signature lines to ensure that appropriate officials have reviewed and approved the request, including individuals responsible for environmental management, worker health and safety, and fire protection

Point-of-Use Storage Request Form Questions (Box 17)

The following questions may be useful to include on a POUS Request Form. A company should be able to answer "yes" to these questions.

General Criteria

- ✓ Will the volume of each chemical used in the POUS be recorded at least 3 times per week?
- ✓ Will each chemical in the POUS be attributed to only one process code?
- ✓ Are there procedures to ensure that no more than a 2-day supply of chemicals is stored in the POUS area?
- ✓ Are there procedures to check shelf life expiration for each chemical in the POUS station?

Environmental and Safety Criteria

- ✓ Is there a stocked, serviceable spill kit within 25 feet of the proposed POUS?
- ✓ Do the flammable storage cabinets conform to OSHA and NFPA 30 Standards?
- ✓ Has the proposed POUS area been inspected to ensure that all safety and other regulatory requirements are met (e.g., electrical hazards)?

Fire Protection Criteria

- ✓ Is there an ABC fire extinguisher within 50 feet of the proposed POUS?
- ✓ Is there a procedure to ensure that flammable chemicals are returned to the cabinets at the end of each shift?

Point-of-Use Storage Set-up and Organization

A point-of-use storage request form can help a facility evaluate whether or not a POUS station or cabinet is appropriate for an area, as well as identify whether additional safety precautions are needed. *Any POUS stations or cabinets should be designed to be well organized, easy to stock and maintain, and clearly labeled.* A storage area should only contain items that are useful to

Key Point

tasks that are performed nearby. It is helpful to avoid having too many of any one item; it is better to stock what is needed for a day or two and restock the POUS as needed. This makes it possible to have a wider variety of items in the POUS station or cabinet, and users will waste less time going to look for a chemical or material when it is needed. In addition, consider storing chemicals using a first in, first out (FIFO) system, so that workers use older chemicals first. This can limit the potential for unnecessary expiration of unused, back-of-shelf chemicals.

Point-of-Use Storage Cabinets (Figure 10)

A POUS station or cabinet should be arranged so that the most frequently used items are easiest to access. Figure 9 shows a picture of a POUS Station. One way to ensure this order is maintained is to have a diagram in the storage area showing where items are located. This makes it easy to restock items in the right place so anyone who uses the materials can easily find them. A diagram of the location of supplies can also enable a person using the POUS station for the first time to easily locate an item. *A helpful rule of thumb is that anyone should be able to find any item in a POUS station in 30 seconds or less*.

Key Point

POUS Maintenance and Housekeeping

Key Point

POUS stations and cabinets should be routinely cleaned, stocked and maintained to ensure that items are in the right place and the station is free of clutter and unnecessary items. Clear policies, procedures, and job expectations should reinforce the role of all employees in maintaining POUS stations in their work areas by putting materials back in the right place and keeping the stations clean and free of trip hazards and other obstructions that can lead to spills.

Other Lean methods discussed in this chapter can help support and reinforce effective cleaning and maintenance of POUS stations. 6S (5S + Safety) can be a powerful Lean method for engaging workers in an area in maintaining and sustaining clean and orderly POUS stations. For example, POUS cleaning and maintenance procedures can be incorporated into 6S (5S + Safety) workplace assessments, shop sweeps and checklists. It may also be appropriate to include POUS cleaning and maintenance activities in standard work procedures for a work area. Box 18 lists several situations that should be routinely checked for and promptly addressed if found. Care should be taken to follow required hazardous waste management practices in situations where it is appropriate to discard chemicals from a POUS station.

Caution

Keep in mind that careful attention is needed to ensure that used chemical containers are properly reused, recycled, or disposed. Look for opportunities to prevent used containers from adding to your organization's hazardous waste stream. It may be possible to clean and reuse or recycle used chemical containers. Consult your facility's EHS personnel for guidance on appropriate practices.

POUS Situations to Look for and Promptly Address (Box 18)

- ✓ Clean dirt, grime, and spills within the POUS station.
- ✓ Properly dispose of or recycle chemicals that are past the expiration date on the container.
- ✓ Properly dispose of or recycle chemicals that have been abandoned or are no longer used in a work area.
- ✓ Fix mislabeled or unlabeled chemicals.
- ✓ Replace containers that are deteriorating or damaged.
- ✓ Properly dispose of or recycle containers in which only residual chemicals remain.
- ✓ Properly dispose of or recycle contaminated or diluted chemicals not appropriate for use.
- ✓ Properly dispose of or recycle debris contaminated with hazardous materials, such as rags, paper towels, gloves, etc.
- ✓ Fix deteriorating signage, instructions and procedures.

Visual Management of Chemicals in the Workplace

Common Lean visual management tools, such as 6S (5S + Safety), visual controls, standard work, and TPM, can be used to make it easier for employees to manage chemicals and hazardous waste in their workspace.

6S (5S + Safety) and Chemical Management

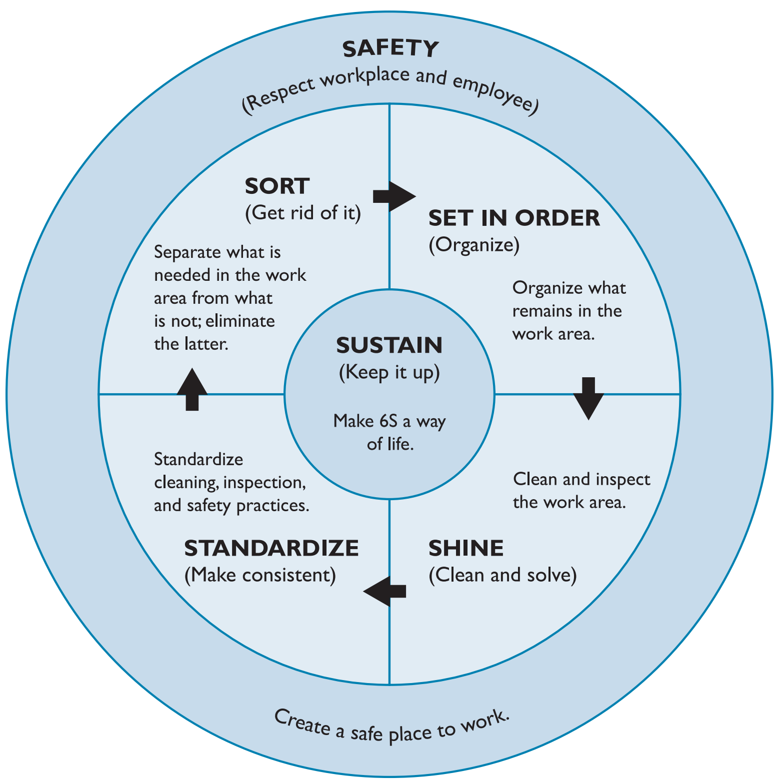
Key Term

6S, or 5S + Safety, is a method used to create and maintain a clean, orderly, and safe work environment. 6S is based upon the five pillars (5S) of the visual workplace in the Toyota Production

System, plus an overall pillar for safety. Each of the 6S pillars is relevant to chemical management. Specific linkages are summarized below:

- **Safety** (Respect workplace and employee): Create a safe place to work that is free of chemical hazards.
- **Sort** (Get rid of it): Separate out and eliminate chemicals that are not needed in the work area.
- **Set in order** (Organize): Organize the chemicals that remain in the work area.
- **Shine** (Clean and solve): Clean and inspect areas where chemicals are stored, used, and disposed.
- **Standardize** (Make consistent): Standardize cleaning, inspection, and safety practices related to chemical management activities and locations.
- **Sustain** (Keep it up): Make sure that chemical management procedures become part of standard work, that problems are quickly addressed, and that systems are routinely assessed for improvement opportunities.

The Six Pillars of 6S (5S + Safety) (Figure 11)



Source: Adapted from Productivity Press Development Team, *5S for Operators: 5 Pillars of the Visual Workplace*, Productivity Press, 1996.

The before and after photos shown in Figure 12 illustrate how the 6S pillars can be applied to transform a POUS station.

6S (5S + Safety) Applied to a POUS Station (Figure 12)

Before After

Caution

It is important to remember that when unnecessary chemicals and substances are discovered in the workplace during a 6S event, they should be carefully and properly managed and disposed of to protect worker safety and to ensure compliance with applicable environmental and safety regulations. EPA's *Lean and Environment Toolkit* discusses how red-tagging can be used during 6S events to flag unneeded chemicals and hazardous wastes. EHS professionals should be contacted to ensure that proper handling and disposal procedures are followed.

Key Questions for Improving Chemical Labeling (Box 19)

- ✓ Are chemicals and hazardous materials clearly labeled and organized?
- ✓ Can you easily identify which chemicals and materials are hazardous?
- ✓ Is it easy to know which chemicals to use first? Can you easily find the expiration dates for chemicals?
- ✓ Do you know where to find information about safety precautions for handling chemicals and hazardous materials?
- ✓ Are containers for disposing of hazardous and non-hazardous wastes clearly labeled and color coded?

Visual Controls, Standard Work and Chemical Management

Key Term

Visual controls are used to reinforce standardized procedures and to display the status of an activity so every employee can see it and take appropriate action. Visual controls can help make sure employees are aware of chemical hazards and are equipped to take appropriate action to handle and manage chemicals appropriately. As discussed in the Point-of-Use Storage Set-up and Organization section above, visual controls can be particularly useful in organizing POUS stations and hazardous waste accumulation and management areas.

Visual Control Examples (Figure 13)

Areas for storing, using and transporting chemicals can also be clearly marked with lines on the floor and signs and placards on walls or hanging from the ceiling to ensure workers see visual cues to remind them of locations where chemicals and hazardous wastes are managed or stored.

Visual controls can also be used for minor tasks, such as helping employees know how much chemical remains in a container or to know how much chemical to put into equipment or a tank. For example, clear containers can make it easy to see the amount of chemicals that remain. Color-coded marking in a tank or tub can assist workers in adding the right amount of chemicals to a process step or piece of equipment.

Key Term

Standard work can also be used to ensure that appropriate chemical management practices become part of routine work practices. *Standard work* refers to an agreed-upon set of work procedures that establish the best and most reliable method of performing a task or operation. Standard work is the final stage of Lean implementation in that it helps sustain previous Lean improvements and serves as the foundation for future continuous improvement (kaizen) efforts.

Key Point

Standard work for a manufacturing cell or Lean workspace should include all actions needed to appropriately manage, use, and dispose of chemicals in the area. If chemical management procedures sit on the shelf in a separate place, they will rarely become part of routine work practice. If chemical management procedures are distinct, such as those related to maintenance of a POUS station, they should be treated like other standard work and made available in the work area for easy reference. Many organizations laminate standard work procedures and hang them in a work station for easy reference.

It may also be useful to code a chemical management standard work step or procedure with an icon (such as a red safety cross or green tree) or number for easy reference back to the organization's Environmental Management System (EMS) or compliance management system.

Total Productive Maintenance and Chemical Management

Key Term

Total Productive Maintenance (TPM) is also relevant to chemical management and waste elimination. TPM is a Lean method that focuses on optimizing the effectiveness of manufacturing equipment. TPM builds upon established equipment-management approaches and focuses on team-based maintenance that involves employees at every level and function.

A key practice in TPM is to maintain equipment and machines in a manner that enables workers to quickly identify and correct problems that may result in leaks or spills of chemicals. Effective routine maintenance may also reduce the amount of chemicals, such as lubricants or solvents, needed to operate equipment.

Box 20 describes several simple steps for safely managing chemicals. These steps fit well with Lean principles such as employee engagement, waste elimination, and continual improvement. Consider integrating these principles into your organization's use of Lean methods such as standard work, TPM, 6S (5S + Safety), and Lean process improvement events.

Managing Chemicals Safely – Nine Simple Steps (Box 20)

1. **Have the right attitude.** Commitment from every employee is essential to a responsible chemical management program.
2. **Know your operation.** Identify the existing hazards, safety requirements, and procedures for clean up, recycling, and disposal.
3. **Reduce the hazards.** Find ways to substitute and change materials in order to use and generate less toxic waste.
4. **People are the key.** Train your employees in proper procedures and practices.
5. **Take charge of change.** A change in one part of a process may change another part so you must plan accordingly.
6. **Protect yourself.** Keep equipment in good shape and conduct regular maintenance reviews.
7. **Learn from mistakes.** Investigate accidents or near accidents, determine the cause, and make the necessary changes.
8. **Be a good citizen.** Work with the industrial community in order to reduce chemical risks.
9. **Once is not enough.** Managing chemicals safely is an ongoing process. Make it an everyday concern.

Source: EPA and OSHA, "Managing Chemicals Safely: Putting it All Together," Publication No. EPA-510-K-92-001, 1992.

To Consider

- Does your company store chemicals at or near where they are used? Is there an approval process for setting up point-of-use storage cabinets?
- What ideas do you have for enhancing the organization and labeling of chemicals, hazardous substances, and waste containers at your facility?
- What particular work areas at your facility could benefit from a 6S (5S + Safety) event to improve workplace organization and chemical safety? (Be sure to include staff with environmental health and safety expertise in events dealing with hazardous chemicals.)
- What work practices (standard work, 6S or 5S, TPM, etc.) could you enhance to reduce chemical wastes from day-to-day operations?

CHAPTER 6
Lean Product and Process Design Methods

Lean product and process design methods are powerful tools for eliminating harmful uses of chemicals in products and processes. This chapter includes the following sections:

- Introduction to Lean Product and Process Design
- Add Environmental Design Criteria to Lean Design Methods
- Draw on Design for the Environment Resources to Find Safer Alternatives
- Use Green Chemistry Principles When Designing Chemical Processes
- A Vision for Lean and Chemicals Efforts

Introduction to Lean Product and Process Design

Lean Product and Process Design Methods

Key Term

Lean design methods are a group of Lean tools and techniques that aim to:

- Design (or redesign) high-quality products that meet customer needs with the least amount of waste (aspects that do not add value); and/or
- Design (or redesign) processes and equipment that add value to products using the least amount of time, material, and capital resources.

By examining the parts and processes that go into product development, Lean practitioners can identify and correct inefficiencies, improve quality, reduce costs, and potentially gain market advantage.

Lean practitioners use a variety of Lean tools for designing (or redesigning) products and processes. Some of these tools are also used in other types of Lean and Six Sigma improvement efforts (e.g., kaizen events). Table 2 describes several of these tools.

Methods Used in Lean Design (Table 2)[12]	
Method	**Description**
Production Preparation Process (3P)	An integrated and highly detailed approach to product and/or process development, which involves rapidly designing production processes and equipment to ensure capability, built-in quality, productivity, and flow. 3P minimizes resource needs such as capital, tooling, space, inventory, and time.
Design for Manufacturing & Assembly (DFMA)	A simultaneous engineering process designed to optimize the relationship between design function, manufacturability, and ease of assembly.
Design for Lean Six Sigma	A method for designing processes that support Lean Six Sigma objectives, such as reduced variability, to improve yield, reduce waste, and accelerate time-to-market.
Value Engineering	An organized methodology that identifies and selects the lowest lifecycle cost options in design, materials, and processes that achieves the desired level of performance, reliability and customer satisfaction. It seeks to eliminate unnecessary costs in the above areas and is often a joint effort with cross-functional internal teams and relevant suppliers.
Quality Function Deployment (QFD) and "Voice of the Customer"	An overall methodology that begins in the design process and attempts to map the customer-defined expectation and definition of quality into the processes and parameters that will fulfill them. It integrates customer interview and market research techniques with internal cross-functional evaluations of the requirements.
Failure Mode & Effects Analysis (FMEA)	A design review methodology that focuses on identifying the potential failure modes of a product, and subsequently determining ways to mitigate each risk of failure.

The Lean method 3P—one of the most powerful and transformative Lean design methods—compresses the creative design process into a multi-day event. Steps in the 3P process include:

- Define design objectives and form the project team
- Select key verbs to describe function

- Sketch and analyze examples from nature
- Identify at least seven ways of doing the operation
- Build, test, and evaluate the best alternatives (This is done rapidly in the context of an event and is often called "try storming" or "boot legging.")
- Coordination (called "catch ball") between product and process design teams (if applicable)
- Evaluate alternatives using design criteria
- Report out presentation and final development of the equipment or product

3P offers organizations the potential to make "quantum leap" improvements in performance, potentially including improvements that eliminate or minimize the use of hazardous chemicals in products and processes.

Product and Process Design Stages

There are six basic stages in the product development process, as follows.

1. **Project Definition**: This stage explores all aspects of a proposed project to examine the relationship between activities, events, durations, and costs. Areas of uncertainty or conflict are identified, and possible alternatives or trade-offs are developed to strike a satisfactory balance.
2. **Conceptual Design**: This stage describes how a new product will work and meet its performance requirements.
3. **Design Validation**: A test is conducted in this stage to ensure that a product fulfills the defined user need and specified performance requirements.
4. **Design Review**: In this stage, a systematic and comprehensive analysis of a design is conducted to determine its capability and adequacy to meet its requirements. During the design review, present and potential problems with the product can be identified.
5. **Qualification Process and Pilot Production**: In this stage, a product is examined to ascertain that it meets required specifications and upon meeting those specifications, it becomes qualified. After a product is qualified, a production line is set up to produce a pilot product.
6. **Production Launch**: This is the last stage in the product design and production process. In this stage, a product is produced by combining all the tangible and intangible inputs necessary to produce the product.

Table 3 shows which Lean tools are appropriate for different stages in the product development process.

Product Design Stages and Appropriate Lean Tools (Table 3)

Method	Stages					
	Project Definition	Conceptual Design	Design Validation	Design Review	Qualification Process and Pilot Production	Production Launch
Production Preparation Process (3P)	X	X	X		X	
Design for Manufacturing & Assembly (DFMA)		X	X	X	X	X
Design for Lean Six Sigma		X	X	X	X	X
Value Engineering	X	X				
Quality Function Deployment (QFD) and "Voice of the Customer"		X	X	X		
Failure Mode & Effects Analysis	X			X		

Add Environmental Design Criteria to Lean Design Methods

Lean design methods often rely on a set of design criteria or principles for evaluating and ranking alternatives. Incorporating environmental design criteria into Lean design methods can help design teams reduce environmental risks in products (e.g., avoid using toxic chemicals) and environmental wastes throughout a product's life cycle. For example, a U.S. furniture manufacturer incorporated environmental design principles, such as use of recyclable materials, into the product design criteria it used to develop a new, high-performance office chair using the 3P method. Box 21 outlines several *product design criteria* that minimize waste and support Lean and environmental objectives.

New Tool

Product Design Criteria (Box 21)

Product Design Criteria that Support Disassembly, Remanufacture, Reuse, and Recycling:

- ✓ Minimize dissimilar materials and number of components
- ✓ Use interchangeable parts
- ✓ Do not use incompatible inks or surface treatments
- ✓ Make hazardous parts components easily detachable
- ✓ Make disassembly easy and efficient
- ✓ Minimize chemical usage and associated waste or emissions

One important way to ensure that design teams consider potential environmental issues and incorporate precautions to protect worker health and safety is to involve environmental health and safety personnel in Lean design events and projects. The *process evaluation questions* in Box 22 below can also help guide Lean teams to design safer and less harmful processes.

New Tool

Process Evaluation Questions from a Chemical Perspective (Box 22)

As your design team is evaluating process alternatives, consider the following questions:

- ✓ Is the process safe?
- ✓ Is it free of chemical-related risks to human health and the environment?
- ✓ Are workers protected from exposure to hazardous chemicals and materials during equipment operation and maintenance?
- ✓ After minimizing chemical use and wastes, are hazardous wastes generated by the process? If so, are there any opportunities for reuse or recycling? Are wastes properly disposed of?
- ✓ Do any chemicals contaminate water and therefore generate a wastewater stream? If so, how can you minimize those wastes?

Draw on Design for the Environment Tools and Resources to Find Safer Alternatives

Key Term

Design for the Environment (DfE) is an approach pioneered by industry for incorporating environmental and health considerations into the design and redesign of products and processes. Like Lean design methods such as 3P, DfE aims to eliminate wastes, uses nature as a model, and involves a systematic evaluation of alternatives-based actual performance data.

New Tool

EPA and other agencies have used DfE approaches to identify *safer technologies and best practices* for minimizing the environmental and human health impacts of different types of manufacturing processes. EPA's Design for Environment Program partners with multiple industrial sectors that use and produce chemicals that are harmful to human health and the environment. Through this program, EPA has identified technology alternatives and best practices to help these sectors mitigate the risks of using hazardous chemicals. Example resources from EPA's DfE program include:

- **Lead-Solder Alternatives for Electronics:** The DfE program has partnered with the electronics industry to evaluate the environmental impacts of tin-lead and lead-free solders. They developed the "Solders in Electronics: A Life-Cycle Assessment" report that contains the results of the potential environmental impacts of selected lead-free solders as alternatives to tin-lead solder.

- **Safer Flame Retardants for Furniture:** By partnering with the furniture industry, the DfE program is helping the industry factor environmental and human health considerations into their decision-making as they choose chemical flame retardants for fire safe furniture foam. This partnership developed "Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam" report that has information on safer alternatives to flame retardants currently in use.

- **Best Practices for Auto Refinishing and Painting:** The DfE program has also partnered with the automotive refinishing sector to increase awareness of the health and environmental concerns associated with refinishing activities and to encourage the use of best practices and safer, cleaner, more efficient practices and technologies. The DfE program has several technical documents available that provide guidance and advice on conventional and best practices for using paint in automotive refinishing.

In addition to these efforts, EPA's DfE Program has many past partnerships with sectors such as:

- Adhesives technology
- Garment & textile care
- Industrial laundry and textile care

- Nail salons
- Printed circuit boards
- Printing industry
- Wire and cable

See Appendix A for additional resources related to reducing chemical use and finding safer alternatives to hazardous chemicals.

Use Green Chemistry Principles When Designing Chemical Processes

Key Term

For businesses that manufacture chemicals or chemical products, consider using green chemistry principles in product design efforts to reduce additional wastes. *Green chemistry* is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle, including the design, manufacture, and use of a chemical product. Green chemistry technologies provide a number of benefits, including:

- Reduced waste, eliminating costly end-of-the-pipe treatments
- Safer products
- Potential reduced use of energy and resources
- Improved competitiveness of manufacturers and their customers

New Tool

The following *12 Principles of Green Chemistry* provide guidance on how to implement green chemistry concepts.[12]

1. **Prevent waste**: Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.
2. **Design safer chemicals and products**: Design chemical products to be fully effective, yet have little or no toxicity.
3. **Design less hazardous chemical syntheses**: Design syntheses to use and generate substances with little or no toxicity to humans and the environment.
4. **Use renewable feedstocks**: Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are the wastes

[12] Paul Anastas and John Warner, *Green Chemistry: Theory and Practice*, Oxford University Press: New York, 1998.

of other processes. Depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are mined.

5. **Use catalysts, not stoichiometric reagents**: Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.
6. **Avoid chemical derivatives**: Making derivatives out of chemicals (e.g., use of blocking or protecting groups, or other temporary modifications) uses additional reagents and generates waste.
7. **Maximize atom economy**: Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
8. **Use safer solvents and reaction conditions**: Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.
9. **Increase energy efficiency**: Run chemical reactions at ambient temperature and pressure whenever possible.
10. **Design chemicals and products to degrade after use**: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. **Analyze in real time to prevent pollution**: Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. **Minimize the potential for accidents**: Design and use chemicals in appropriate phases (solid, liquid, or gas) to minimize the potential for chemical accidents, including explosions, fires, and releases to the environment.

EPA's Green Chemistry Program (www.epa.gov/greenchemistry) and Sustainable Futures Program (see Box 23) provide many tools and resources for chemical manufacturers interested in incorporating green chemistry concepts into their product design processes. Appendix A describes a range of resources and tools for finding safer alternatives to hazardous chemicals; these resources are applicable to a broad range of facilities that use chemicals.

EPA's Sustainable Futures Program (Box 23)

EPA's Sustainable Futures Program provides chemical developers access to computer-based risk-screening methods and models for the development of new chemicals. Chemical manufacturers can use these tools to detect potentially hazardous chemicals early on in the development process and to find less hazardous substitutes for the chemicals they are producing.

The Sustainable Futures Program provides training to companies on how to use these models to prescreen their chemicals. Companies that participate in this program may also be eligible for expedited EPA review of their chemicals. The program has been successful at encouraging companies to develop safer, less hazardous chemicals.

For more information, visit the EPA's Sustainable Futures Program website at www.epa.gov/oppt/sf.

A Vision for Lean and Chemicals Efforts

As described in more detail in the Preface, a guiding vision for Lean and chemicals efforts could include the following two long-term goals:

- Produce high-quality products and services that do not contain hazardous chemicals that customers did not request.
- Develop products that can decompose naturally at the end of their use or become high-quality raw materials for new products.

These goals draw from the "cradle to cradle" design concepts outlined by William McDonough and Michael Braungart.[13] While all the strategies and tools in this toolkit can support these goals, leveraging Lean design methods to eliminate chemical wastes and integrate environmental design principles potentially offer the greatest opportunities to make radical or "quantum leap" improvements to help achieve this vision.

[13] William McDonough and Michael Braungart, *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, 2002.

To Consider

- Does your company use Lean methods of product and/or process design? If so, what opportunities do you see for incorporating environmental principles or criteria into those efforts?
- Have you used Design for Environment or Green Chemistry principles and tools in designing or redesigning products and processes at your company?
- When your company designs a new process or redesigns an existing process, do you consider using or substituting environmentally preferable chemicals, solvents, and cleaners?
- What steps would you take to incorporate environmental design criteria into your facility's product and process design efforts?

CHAPTER 7
Conclusion

The following sections are included in this chapter:

- Getting Started with Lean and Chemicals
- Partners for Success

Getting Started with Lean and Chemicals

We hope this toolkit has given you some practical ideas for leveraging Lean methods to identify and eliminate chemical waste in your organization. Once you learn to see chemical waste in the context of Lean, the magnitude of the system-wide costs of using, managing, and disposing of chemicals can be surprising. There are many ways to get started using Lean to reduce chemical wastes and improve operational results. As described in further detail in Chapter 1, here are three ways to get started with Lean and chemicals.

1. **Begin the Conversation.** Arrange a meeting between Lean leaders and environmental health and safety managers at your organization to discuss opportunities to reduce chemical wastes with Lean.
2. **Make Chemicals and Their Costs Visible.** Start measuring chemical use and hazardous waste generation along with Lean metrics. Consider adding environmental wastes to the "deadly wastes" targeted by Lean.
3. **Piggyback on Lean Visual Management Efforts.** Use Lean visual management strategies and tools such as 6S (5S + Safety), visual controls, and standard work to make it easy for workers to properly manage and dispose of chemicals and hazardous wastes.

While these steps can yield results fast, thinking about how chemicals fit in your organization's longer term Lean journey can uncover even bigger opportunities. In particular, Lean product and process design methods and organizational improvement strategies such as Chemical Management Services, can yield substantial improvements for your organization.

Partners for Success

Government and industry can work together to foster innovation and share ideas for reducing chemical wastes using Lean. In many areas, innovation and collaboration will be essential to achieving the "cradle to cradle" Lean and chemicals vision discussed in the Preface—that is, the vision that products do not contain hazardous chemicals that customers did not ask for and that products, at the end of their useful life, can decompose naturally or become high-quality raw materials for new products. Fortunately, numerous efforts involving individual companies, trade associations, and government are already underway to reduce the use of hazardous chemicals in products and processes.

EPA supports several programs that help companies reduce chemical wastes, find safer alternatives to hazardous chemicals, and develop greener chemical products. These programs include:

- Design for Environment Program (www.epa.gov/dfe)
- Green Chemistry and the Presidential Green Chemistry Challenge Awards (www.epa.gov/greenchemistry)
- Green Engineering Program (www.epa.gov/oppt/greenengineering)
- Green Suppliers Network Program (www.greensuppliers.gov)
- High Production Volume Challenge Program (www.epa.gov/chemrtk/pubs/general/basicinfo)
- Lean and Environment Initiative (www.epa.gov/lean)
- National Partnership for Environmental Priorities (www.epa.gov/npep)
- Resource Conservation Challenge (www.epa.gov/rcc)
- Sector Strategies Program (www.epa.gov/sectors)
- Sustainable Futures Program (www.epa.gov/oppt/sf)

Appendix D provides additional information about each of these programs. Consider getting involved in one or more of these efforts. EPA is committed to supporting your efforts to achieve success with your Lean and chemicals efforts.

We hope this toolkit spurs creative thinking and energy within your organization and encourages you to explore these opportunities. We also hope to learn from your experiences using this toolkit. Working with partner companies and organizations, we aim to periodically release new versions of resources in EPA's Lean and Environment Toolkit series. Our hope is to refine the techniques presented, provide examples and case studies of their application, and address new techniques. We wish you success on your Lean and chemicals journey.

Your Thoughts on the Toolkit

Now that you have finished this toolkit, reflect on what you read by answering these questions:

- What strategies and tools in the toolkit seemed particularly interesting and useful?
- What steps will you take next to advance Lean and efforts at your organization?
- What other information and tools would assist your organization to realize your Lean and chemicals vision?

APPENDICES

Appendix A

Chemical Resources

This appendix describes resources and places to go for more information concerning the following topics:

- Resources for Understanding Attributes of Chemicals
- Tools for Reducing Chemical Use and Finding Alternative Chemicals
- Technical Assistance Providers

Resources for Understanding Attributes of Chemicals

Agency for Toxic Substances and Disease Registry ToxFAQs Fact Sheets

www.atsdr.cdc.gov/toxfaq.html

The Agency for Toxic Substances and Disease Registry (ATSDR) ToxFAQs Fact Sheets are a series of summaries about hazardous substances. Information for this series is excerpted from the ATSDR Toxicological Profiles and Public Health Statements. Each fact sheet serves as a quick and easy to understand guide. Answers are provided to the most frequently asked questions (FAQs) about exposure to hazardous substances found around hazardous waste sites and the effects of exposure on human health.

Department of Transportation Emergency Response Guide

http://phmsa.dot.gov/hazmat/library/erg

The U.S. Department of Transportation, Transport Canada, and the Secretariat of Communications and Transportation of Mexico developed the Emergency Response Guide (ERG). The ERG provides information to police, firefighters, and other emergency personnel when responding to an incident involving hazardous goods or materials. The guide provides information on how to identify which hazardous materials are involved in an incident, how to identify how hazardous the material is, and steps to take during an incident involving hazardous materials. Although the primary audience for the guide is emergency responders, the safety information in the guide is a good resource to anyone working with hazardous materials.

EPA's Health Effects Notebook for Hazardous Air Pollutants

www.epa.gov/ttnatw01/hlthef

The fact sheets available on this website describe the effects on human health of substances that are defined as hazardous by the 1990 amendments of the Clean Air Act. These substances include certain volatile organic chemicals, pesticides, herbicides, and radionuclides that present tangible hazard, based on scientific studies of exposure to humans and other mammals.

EPA's Integrated Risk Information System (IRIS)

http://cfpub.epa.gov/ncea/iris/index.cfm

EPA's Integrated Risk Information System (IRIS) is a compilation of electronic reports on specific substances found in the environment and their potential to cause human health effects. IRIS was initially developed for EPA staff in response to a growing demand for consistent information on:

- substances for use in risk assessments
- decision-making and
- regulatory activities

The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences.

Hazardous Substances Data Bank

http://toxnet.nlm.nih.gov

The National Library of Medicine's Toxicology Data Network (TOXNET) contains multiple databases on chemicals. Hazardous Substances Data Bank (HSDB) is a toxicology data file on TOXNET that focuses on the toxicology of potentially hazardous chemicals. It is has information on:

- human exposure
- industrial hygiene
- emergency handling procedures
- environmental fate
- regulatory requirements

All data are referenced and derived from a core set of books, government documents, technical reports, and selected primary journal literature. HSDB is peer-reviewed by the Scientific Review

Panel, a committee of experts in the major subject areas within the data bank's scope. HSDB is organized into individual chemical records and contains over 5000 such records.

Haz-Map: Occupational Exposure to Hazardous Agents

http://hazmap.nlm.nih.gov

Haz-Map is an occupational toxicology database designed to link occupations associated with the production and use of chemicals to hazardous tasks that people perform at these occupations that are linked to occupational diseases and their symptoms. It is a relational database of chemicals, jobs and diseases. You can browse Haz-Map by the following categories:

- Hazardous Agents
- Occupational Diseases
- High Risk Jobs

National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards

www.cdc.gov/niosh/npg

The NIOSH Pocket Guide is a source of general industrial hygiene information on several hundred chemicals for workers, employers, and occupational health professionals. This resource is further described in Chapter 2 of this toolkit.

OSHA/EPA Occupational Chemical Database

www.osha.gov/web/dep/chemicaldata

This database compiles information from several government agencies and organizations. It was developed by the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) and the U.S. Environmental Protection Agency (EPA) as a convenient reference for the occupational safety and health community. It contains the information on individual chemicals. You can search the database by chemical name or CAS Number. The database includes the chemical name, CAS number, synonyms, and reports for each chemical.

Included in the chemical description are the following database reports:

- Physical Properties
- Exposure Guidelines
- NIOSH Pocket Guide entry

- Emergency Response Information including the Department of Transportation Emergency Response Guide

PBT Profiler

www.epa.gov/oppt/sf/tools/pbtprofiler.htm

The PBT Profiler is a simple, web-based chemical screening tool from the EPA's Sustainable Futures Program. PBT stands for "Persistent, Bioaccumulative, and Toxic" and refers to attributes of certain chemicals. This tool allows users to predict a chemical's ability to persist in the environment, its tendency to bio-accumulate in animals, and its toxicity level. The tool can help prioritize chemicals based on their environmental attributes.

Tools for Reducing Chemical Use and Finding Alternative Chemicals

ChemAlliance.org Resources

www.chemalliance.org

ChemAlliance.org provides information about environmental regulations that affect the chemical industry. The website contains articles, information, regulatory compliance tools, and information on pollution prevention for the chemical industry. The information is relevant for technical assistance providers, small and large businesses, regulators, and environmental professionals.

An example of a resource available from ChemAlliance.org is its webpage on "Pollution Prevention Options for Chemical Manufactures," www.chemalliance.org/Articles/Improving/P2_Options_for_Chem_Manufacturers.asp. The webpage lists common places were waste originates, the type of waste produced, and it provides methods for waste prevention and recycling it. Pollution prevention options are described for topics such as:

- Material Input, Storage and Handling
- Reactors
- Pumps
- Heat Exchangers
- Distillation Column
- Piping
- Furnaces

CleanerSolutions Database

www.cleanersolutions.org

The Surface Solution Laboratory (SSL) at the Massachusetts-based Toxics Use Reduction Institute has created this database linking performance evaluations to specific testing parameters and environmental assessments based on the testing performed at the lab. SSL was designed with the capability to evaluate the effectiveness of different cleaning chemistries and equipment for a variety of substrates and contaminants. The goal of SSL is to assist industry in the search for safer cleaning processes by developing and promoting safer alternatives to hazardous solvents with a special focus on aqueous/semi-aqueous cleaners and state-of-the-art surface cleanliness analyses.

Design for the Environment Toolkit from the Minnesota Pollution Control Agency

www.pca.state.mn.us/oea/publications/dfetoolkit.pdf

The Minnesota Pollution Control Agency has developed a Design for the Environment Toolkit that helps designers incorporate environmental attributes into existing product design practices. The toolkit develops a numerical score for a product to show where that product is strong and where it needs improvement with regards to environmental concerns.

Eco-Efficiency and Chemical Management Fact Sheets

http://eco-efficiency.management.dal.ca/Publications_%26_Resources/Business_Fact_Sheets.php

The Eco-Efficiency Centre is a non-profit organization based in Eastern Canada that provides management support and resources for small and medium sized enterprises. The Centre has developed a series of fact sheets on chemical reduction. For example, the Centre has developed a general fact sheet on chemical waste reduction titled, "Eco-Efficiency and Chemical Management: Opportunities and Best Practices." This fact sheet addresses the following topics:

- Understanding the chemicals in your business
- Good housekeeping (includes strategies on policy, purchasing of chemicals, storage and inventory, and maintenance)
- Chemical substitution (includes strategies on product changes, process changes, equipment changes, in-process recycling, reuse, recycle and treat waste, and solvent use alternatives)
- Responsible chemical management

EPA Environmentally Preferable Purchasing Database

http://yosemite1.epa.gov/oppt/eppstand2.nsf

EPA's Environmentally Preferable Purchasing (EPP) Program helps the federal government purchase environmentally friendly goods and services. The EPA has developed a database of environmental information for products and services. This database allows federal purchasers to find product specific information including:

- Contract language, specifications, and policies
- Environmental standards and guidelines
- Lists of vendors that meet these standards
- Other information

The EPA updates this database on regular basis. It allows users to search from a list of topic areas or users can search by a specific product. Although this tool was designed for use by federal agencies, it is available for viewing by the public.

General Services Administration (GSA) Environmental Specialty Catalog

https://www.gsaadvantage.gov/advgsa/advantage/search/specialCategory.do?cat=ADV.ENV

The U.S. GSA Advantage Environmental Specialty Catalog contains products and services that assist federal agencies with their environmental purchasing goals. The catalog allows direct access to a variety of environmental products and services designated as bio-based and recycled content, ENERGY STAR, water efficient, and non-ozone depleting materials. Although only federal, state, and local government agencies can purchase products from the GSA Environmental Specialty Catalog, it is available for anyone to browse.

Global Environmental Management Initiative Guide to Strategic Sourcing for Environment, Health, and Safety

www.gemi.org/resources/newpath.pdf

The Global Environmental Management Initiative developed the guidance document, "New Paths to Business Value: Strategic Sourcing—Environment, Health and Safety," to help businesses strengthen their environmental, health, and safety (EHS) performance by through making responsible procurement decisions such as purchasing green products. The document covers five topic areas that explain how strategic sourcing can improve a company's EHS performance. The five areas are organized to answer the following questions:

1. Is EHS an important source of business value in the supply chain?
2. How are untapped business values in the supply chain found?
3. How can EHS criteria add to business value?
4. How can supplier EHS performance be improved?
5. How can EHS performance be improved through outsourcing?

Green Chemical Alternatives Purchasing Wizard

http://web.mit.edu/environment/academic/purchasing.html

The Green Chemical Alternatives Purchasing Wizard is a web-based tool that allows the user to search from a select list of solvents commonly used in the laboratory and the associated process. The Wizard identifies less hazardous and more environmentally benign chemicals or processes that may be substituted, and provides journal references as well as website URLs to information that is available online. Users may print article information or have email sent with the URL for the article reference.

Green Chemistry Expert System

www.epa.gov/oppt/greenchemistry/pubs/tools.html

The Green Chemistry Expert System allows users to build a green chemical process, design a green chemical, or survey the field of green chemistry. The system is equally useful for new and existing chemicals and their synthetic processes. It includes extensive documentation.

The Green Chemistry Expert System features are contained in five modules:

- The Synthetic Methodology Assessment for Reduction Techniques (SMART) module quantifies and categorizes the hazardous substances used in or generated by a chemical reaction, based on information entered by the user. Reactions can be modified in the SMART module and re-evaluated to optimize their green nature.
- The Green Synthetic Reactions module provides technical information on green synthetic methods.
- The Designing Safer Chemicals module includes guidance on how chemical substances can be modified to make them safer; it is organized by chemical class, properties, and use.
- The Green Solvents/Reaction Conditions module contains technical information on green alternatives to traditional solvent systems. This module also allows users to search for green substitute solvents based on physicochemical properties.

- The Green Chemistry References module allows the user to obtain additional information using a number of search strategies. The user may also add references to this module.

Green Cleaning Pollution Prevention Calculator

www.ofee.gov/janitor/index.asp

The Green Cleaning Pollution Prevention Calculator quantifies the projected environmental benefits of purchasing and using "green" janitorial services and products. It is designed to forecast the environmental benefits of reducing chemical use by doing some or all pollution prevention measures typically involved in the routine interior cleaning of an office building. This tool also enables users to identify which green cleaning measures will have the greatest impact in reducing their use of hazardous chemicals and in preventing pollution.

The calculator's output applies only to standard office cleaning products and practices, and does not apply to other building maintenance issues, such as equipment maintenance, pest control, or landscaping activities.

The Green Screen for Safer Chemicals

www.cleanproduction.org/Greenscreen.php

The "Green Screen for Safer Chemicals" developed by the not-for-profit organization Clean Production Action is a tool that can help manufactures make informed decisions about the chemicals they use. The tool informs manufactures of the hazard associated with a particular chemical and guides manufactures in choosing less hazardous chemical options through a process if informed substitution. The tool includes a "Red List of Chemicals" that lists chemicals of high concern. Manufactures can view this list to identify hazardous chemicals at use in their facilities. The Green Screen defines four benchmarks that have to be met to ensure that the safest chemical is being used. The four benchmarks are:

1. Avoid Chemicals of High Concern
2. Use but Search for Safer Substitutes
3. Use but Still Opportunity for Improvement
4. Prefer Safer Chemicals

Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)

www.epa.gov/nrmrl/std/sab/traci

The EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) database provides a way to research and compare various human health and environmental impacts of different kinds of chemicals. It was developed to assist in impact assessment for: sustainability metrics life cycle assessment, industrial ecology, process design, and pollution prevention. Methodologies were developed specifically for the U.S., using input parameters consistent with US locations for the following impact categories:

- acidification
- smog formation
- eutrophication
- human cancer
- human non-cancer
- human criteria effects

TRACI's modular design allows the compilation of the most sophisticated impact assessment methodologies that can be utilized in software developed for PCs.

Technical Assistance Providers

Pollution Prevention Research Exchange (P2Rx) Consortium

www.p2rx.org

The Pollution Prevention Resource Exchange (P2Rx™) is a consortium of eight regional pollution prevention information centers in the U.S., funded in part through grants from EPA. These centers all provide pollution prevention information, networking opportunities and technical assistance services to States, local governments and technical assistance providers in their region.

The regional P2Rx centers include the following:

- Great Lakes Regional Pollution Prevention Information Center (IL, IN, MI, MN, NY, OH, PA, WI, and Ontario, Canada), www.glrppr.org
- Northeast Waste Management Officials' Association (CT, MA, ME, NH, NJ, NY, RI, and VT), www.newmoa.org

- Pacific Northwest Pollution Prevention Resource Center (WA, ID, OR, and AK), www.pprc.org
- Peaks to Prairies Pollution Prevention Information Center (CO, MT, ND, SD, UT, and WY), http://peakstoprairies.org
- Pollution Prevention Regional Information Center (IA, KS, MO, and NE), www.p2ric.org
- Southwest Network for Zero Waste (AR, LA, NM, OK, and TX), www.zerowastenetwork.org
- Waste Reduction Resource Center (AL, DC, DE, FL, GA, KY, MD, MS, NC, PA, SC, TN, VA, and WV), http://wrrc.p2pays.org
- Western Regional Pollution Prevention Network (AZ, CA, HI, and NV), www.wrppn.org

National Institute of Standards and Technology Manufacturing Extension Partnership

www.mep.nist.gov

The National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (MEP) is a network of manufacturing assistance centers that provide Lean manufacturing training, Lean event facilitation, and other services to small-to-medium sized businesses to make them more competitive. Many MEP centers have experience providing integrated Lean and environmental services to businesses or have partnerships with environmental agencies to offer Lean and environment services.

Appendix B

Material Safety Data Sheet Template Example

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910 1200. Standard must be consulted for specific requirements.

U.S. Department of Labor

Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

IDENTITY (as Used on Label and List)	**Note: Blank spaces are not permitted. If any item is not applicable or no information is available, the space must be marked to indicate that.**

Section I

Manufacturers Name	Emergency Telephone Number
Address (Number, Street, City, State and ZIP Code)	Telephone Number for Information
	Date Prepared
	Signature of Preparer (optional)

Section II—Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity, Common Name)	OSHA PEL	ACGIH TLV	Other Limits Recommended	Percent (optional)

Section III—Physical/Chemical Characteristics

Boiling Point		Specific Gravity (H_2O=1)	
Vapor Pressure (mm Hg)		Melting Point	
Vapor Density (AIR = 1)		Evaporation Rate (Butyl Acetate = 1)	

Solubility in Water

Appearance and Odor

Section IV—Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL

Extinguishing Media

Special Fire Fighting Procedures

Unusual Fire and Explosion Hazards

(Reproduce locally) OSHA
174 Sept. 1985

Source: U.S. Department of Labor, Material Safety Data Sheet, available on the U.S. Chamber of Commerce website, http://business.uschamber.com/tools/osh174_m.asp.

Appendix C

Point-of-Use Storage Request Form Example

POINT-OF-USE STORAGE REQUEST FORM			**Page 1 of 2**
1. REQUESTOR'S NAME AND PHONE NUMBER			2. REQUESTOR'S ORGANIZATION
3. DATE	4. BUILDING/SHOP		5. HAZARDOUS MATERIALS MANAGEMENT SYSTEM ZONE
General Information Regarding the POU Area:			
6. SUPERVISOR RESPONSIBLE FOR POU AREA	7. OFFICE	8. PHONE NUMBER	9. E-MAIL ADDRESS
10. PARTY RESPONSIBLE FOR MAINTAINING THE HAZARDOUS MATERIALS IN THE POU AREA (E.G., PHARMACY, TOOL CRIB, ETC.)			

11. INSTRUCTIONS

The attached checklist is to be used as an internal procedure to provide information to ensure that the Point-of-use (POU) method for issuing hazardous material is appropriate from a compliance standpoint. This form should be submitted to the Environmental Health and Safety Department for review. Procedures for the POU cabinet should be attached.

The form is designed so that if all of the questions are answered with "Yes" responses, the application can be approved. If any question is answered with a "No" response, additional sheets outlining the proposed procedure(s) must be attached for review. Questions should be directed to the Environmental Coordinator. For general questions, contact ____ at XXX-XXX-XXXX.

What chemical(s) will be placed in the POU area?

	Chemical Name	**NSN**	**Unit of Issue**	**Process Code**	**Total Volume**
a.					
b.					
c.					
d.					
e.					

(attach additional sheets if required)

13. INITIATOR'S SIGNATURE	ORGANIZATION	PHONE	DATE
14. APPROVAL SIGNATURE	ORGANIZATION	PHONE	DATE

POINT-OF-USE STORAGE REQUEST FORM	**Page 2 of 2**	
If any of the following questions are answered "No," additional sheets outlining the proposed procedure must be attached.		
General Criteria:	**Y**	**N**
Has a map showing the locations of all flammable and corrosive cabinets (including this POU area) that are bounded within the fire zone been attached to this application?	☐	☐
If there are multiple cabinets within the fire zone, have the volume and type of chemical in each cabinet been indicated on the map?	☐	☐
Environmental Criteria:	**Y**	**N**
Will the volume of each chemical used be recorded in the hazardous materials management system at least 3 times per week?	☐	☐
Will each chemical stored at the POU area be directly attributed to a single process code?	☐	☐
Is the current issue method a hazardous material pharmacy?	☐	☐
Are there procedures to ensure that no more than a 2-day supply of chemicals is maintained at the POU are?	☐	☐
Are there procedures to check shelf life expiration for each chemical at the POU area?	☐	☐
Is there a stocked, serviceable spill kit within 25 feet of the proposed POU area?	☐	☐
Will the existing IAPs be used with no changes to the waste descriptions or additional drums needed?	☐	☐
Safety Criteria:	**Y**	**N**
Do the flammable storage cabinets conform to OSHA and NFPA 30 Standards?	☐	☐
Do the corrosive storage cabinets conform to appropriate safety standards?	☐	☐
Location/area was inspected to ensure all safety requirements are met (e.g. electrical hazards, operational compatibility, etc.)	☐	☐
Fire Protection Criteria:	**Y**	**N**
Including the chemicals at this POU area, will the total volume of Class I, II, and IIIA chemicals be less than 360 gallons in the fire area?	☐	☐
Will the total volume of Class I, II, and IIIA liquids stored in any one cabinet be less than 120 gallons?	☐	☐
Will the total volume of Class I and II liquids stored in any one cabinet be less than 60 gallons?	☐	☐
Are the cabinets in the fire zone, including the cabinets for this POU, numbered and are the numbers indicated on the attached map?	☐	☐
Is there an ABC fire extinguisher within 50 feet of the proposed POU area?	☐	☐
Is there a procedure in place to ensure that flammables are returned to the cabinets at the end of each shift?	☐	☐

Concur/Nonconcur – See Attachment _____

Concur/Nonconcur – See Attachment ____

____
Environmental Management

____
Safety

Appendix D

EPA Programs That Support Chemical Waste Reduction Efforts

This appendix describes the following EPA programs that help companies reduce chemical wastes, find safer alternatives to hazardous chemicals, and develop greener chemical products.

- Design for Environment Program
- Green Chemistry and the Presidential Green Chemistry Challenge Awards
- Green Engineering Program
- Green Suppliers Network Program
- High Production Volume Challenge Program
- Lean and Environment Initiative
- National Partnership for Environmental Priorities
- Resource Conservation Challenge
- Sector Strategies Program
- Sustainable Futures Program

Design for the Environment

www.epa.gov/dfe

The Design for the Environment (DfE) program works in partnership with a range of industry, non-governmental organizations, and other relevant stakeholders to integrate health and environmental considerations into business decisions. DfE focuses on industries that combine the potential for chemical risk reduction with a strong motivation to make positive, lasting change. As incentives for participation and driving change, DfE offers unique technical tools. The DfE resources are further described in Chapter 6 of this toolkit.

Green Chemistry and the Presidential Green Chemistry Challenge Awards

www.epa.gov/greenchemistry

EPA's Green Chemistry promotes innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in the design, manufacture, and use of chemical products. The program works towards its goals by supporting green chemistry research, education, outreach, and incentive opportunities to scientists and industrial decision makers. The program also runs the Presidential Green Chemistry Challenge, an awards program that recognizes outstanding green chemistry technologies.

Green Engineering Program

www.epa.gov/oppt/greenengineering

The goal of the Green Engineering Program is to promote the research and use of green engineering approaches and techniques in production and design. Green engineering is the design, commercialization, and use of processes and products, which are feasible and economical while minimizing 1) generation of pollution at the source, and 2) risk to human health and the environment. The program hopes to institutionalize green thinking in the design and commercialization of products and processes through educational outreach, and collaborative projects with industry, regions, and other stakeholders. It hopes to go beyond focusing on waste.

Green Suppliers Network Program

www.greensuppliers.gov

The Green Suppliers Network is a partnership program among industry, EPA, and the US Department of Commerce's Manufacturing Extension Partnership to green America's manufacturing supply chains. Green Suppliers works with all levels of the manufacturing supply chain to improve processes and minimize waste generation. Through on-site reviews, suppliers continuously learn ways to increase energy efficiency, identify cost-saving opportunities, and optimize resources and technologies to eliminate waste. This results in more effective processes and products with higher profits and fewer environmental impacts.

High Production Volume (HPV) Challenge

www.epa.gov/chemrtk/pubs/general/basicinfo

The HPV Challenge Program is a collaborative partnership program designed to ensure that the American public has access to information to make informed decisions about chemicals encountered in their daily lives. HPV chemicals are those that are manufactured or imported into the United States in amounts equal to or greater than one million pounds per year. Since the Program's inception, chemical manufacturers and importers have participated by sponsoring over 2,200 chemicals. Sponsorship involves a commitment to develop data summaries of relevant existing information and to conduct testing to fill any data gaps. This collection of screening-level hazard data produced in the largest quantities is publicly available on the HPV Challenge Program website and in the HPV Information System (HPVIS).

Under the High Production Volume Challenge Program, companies are "challenged" to make health and environmental effects data publicly available on chemicals produced or imported in the United States in the greatest quantities. HPV chemicals are classified as those chemicals produced or imported in the United States in quantities of 1 million pounds or more per year. As of June 2007, companies have sponsored more than 2,200 HPV chemicals, with approximately 1,400 chemicals sponsored directly through the HPV Challenge Program and over 860 chemicals sponsored indirectly through international efforts.

Lean and Environment Initiative

www.epa.gov/lean

Recognizing that Lean trends have implications for both regulatory and non-regulatory programs, EPA is working with Lean experts, organizations implementing Lean, state environmental agencies, and other partners to:

- Raise awareness about the relationship of Lean production to environmental performance
- Share "good practices" for improving the environmental benefits of Lean initiatives
- Develop and disseminate integrated Lean and environment tools
- Identify and address environmental regulatory considerations associated with Lean
- Explore how Lean techniques might be used to improve government administrative processes (e.g., permitting)

EPA is working with partners in a number of industry sectors and in government agencies to document Lean and environment success stories and to develop and test tools that organizations could use to maximize the environmental benefits of Lean. In addition, EPA is conducting outreach about Lean and the environment to Lean practitioners and pollution prevention (P2) technical assistance providers. Finally, EPA is working with states to apply Lean techniques to streamline permitting.

National Partnership for Environmental Priorities

www.epa.gov/npep

The National Partnership for Environmental Priorities under the Resource Conservation Challenge (RCC) is a partnership program designed to result in the reduction in the use (and consequently waste) of 31 priority chemicals (see Table 1 in Chapter 2) that the Agency has determined to be persistent bioaccumulative toxics (e.g., dioxin and mercury). Partners are enrolled in the program by regional partnership recruiters, who, when necessary, conduct site visits and assist facilities in determining where priority chemical reductions can be achieved.

Resource Conservation Challenge

www.epa.gov/rcc

The Resource Conservation Challenge (RCC) is EPA's national effort to conserve natural resources and energy by managing materials more efficiently. The goals of the RCC are to:

- Prevent pollution and promote reuse and recycling
- Reduce priority and toxic chemicals in products and waste
- Conserve energy and materials

The results of these national efforts are significantly reducing greenhouse gas emissions and saving tremendous amounts of energy annually.

Sector Strategies Program

www.epa.gov/sectors

The multi-media Sector Strategies Program promotes widespread improvement in environmental performance, with reduced administrative burden, in twelve major manufacturing and service sectors: agribusiness, cement manufacturing, chemical manufacturing, colleges and universities, construction, forest products, iron and steel manufacturing, metal casting, oil and gas exploration and refining, paint and coatings, ports, and shipbuilding. Stakeholders work collaboratively to address performance barriers and prompt industry-wide stewardship initiatives, such as the National Mercury Switch Removal Program that was launched in 2006.

Sustainable Futures Program

www.epa.gov/oppt/sf

EPA's Sustainable Futures Program is a partnership program that provides chemical developers access to computer-based risk-screening methods and models for the development of new chemicals. Chemical manufacturers can use these tools to detect potentially hazardous chemicals early on in the development process and to find less hazardous substitutes for the chemicals they are producing. The Sustainable Futures Program provides training to companies on how to use these models to prescreen their chemicals. Companies that participate in this program may also be eligible for expedited EPA review of their chemicals. The program has been successful at encouraging companies to develop safer, less hazardous chemicals.



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